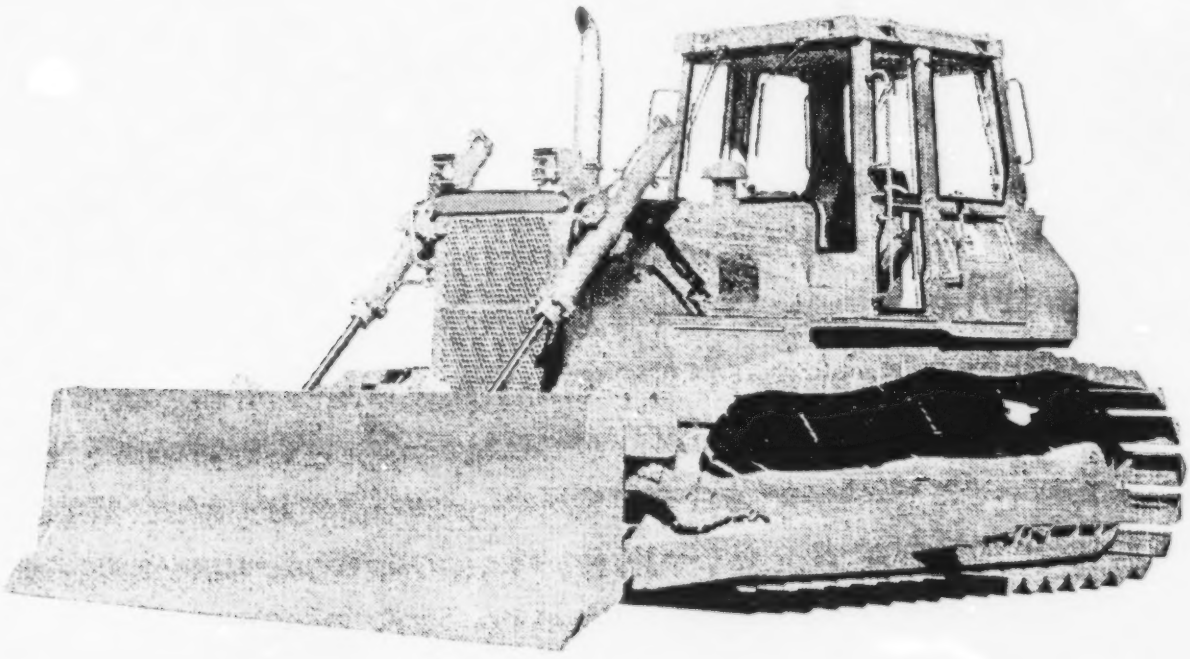
FIRELINE CONSTRUCTION

BULLDOZER PRODUCTION RATES AND GUIDELINES FOR CONSTRUCTING FIREGUARDS IN BOREAL FOREST COVER TYPES



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R.L. Ponto
Fairview, Alberta

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BULLDOZER PRODUCTION RATES AND GUIDELINES FOR CONSTRUCTING FIREGUARDS IN BOREAL FOREST COVER TYPES

1.0 INTRODUCTION

Fire suppression methods and techniques continue to evolve and improve firefighting effectiveness under adverse conditions. The availability of bulldozers of a superior design, combined with the accumulated experience and knowledge regarding their use, has better organized firefighting and increased the amount of work that can be done in that area.

The role of bulldozers in fighting wildfires continues to be influenced by safety factors, productivity and the numerous environmental aspects that must be considered. While bulldozers are a valuable tool for firefighting, their use is a privilege, not a requirement, and they could become subject to restrictions should any aspect of their prescribed use not be adhered to.

Bulldozers have become an important component of an integrated fire suppression network. Also included in this network are helitankers, airtankers, specialized ground crews, aerial and ground retardant, foam application, etc. These all have the same objective of quickly subduing the spread of forest fires with efficiency, minimum cost, reduced loss and diminished environmental damage.

Ideally, forest officers or certified cat bosses who are placed in the position of supervising bulldozer operations on wildfires, possess extensive experience in this area. However, because of manpower shortages during periods of high fire hazard and frequency, less experienced personnel often fill these positions (e.g., uncertified

cat bosses). These people have demonstrated that it is possible to do a good job even if they possess only a basic knowledge of the duties, providing they incorporate the knowledge and experience of bulldozer operators and overhead staff into their decisions.

A bulldozer is primarily used to provide a fuel break to contain the spread of the fire. The type, size and mechanical condition of the bulldozer, as well as the skill, supervisory abilities and organization of the operator, will determine the success of the suppression efforts and the amount of reclamation work that will be required.

To date, little information is available regarding actual bulldozer production levels for boreal forest types. In the following material, an attempt has been made to combine the results of a bulldozer productivity study undertaken by the Northern Forestry Centre (NOFC), with the experience of forest personnel and contractors in order to determine common problems and develop solutions for a range of fireline conditions. Results of the NOFC study were derived from a database that incorporated approximately 200 km or 600 hours of actual bulldozer fireguard construction during wildfires. It is hoped that this information will provide a better understanding of each party's concerns and result in safer working conditions, greater productivity and improved worker morale.

It is not expected that all personnel working in the area of fire control will agree with all aspects of this report. This document was based on the experiences of several people; however, such experiences may not correlate with those of others.

There is probably no other circumstance where forestry personnel and contractors are scrutinized more intensely than on large campaign fires. The memories of how well or how poorly the fires were responded to continue long after the fire has been mopped-up. Good organization

and supervision will contribute greatly to how the public views the handling of the fire operation.

2.0 BULLDOZER ORGANIZATION

2.1 Role of Bulldozers for Fire Control

Bulldozers are capable of performing a wide range of duties when their operations are properly organized and supervised. Their duties include the following:

- upgrading roads into the fire;
- clearing and leveling campsites and constructing garbage pits;
- constructing fireguards;
- constructing helicopter landing pads;
- mop-up duties;
- restoration of fireguards; and
- integrated functions such as walking down fuels before back-burning, constructing creek crossings, etc.

2.2 Organizing Bulldozer Units

2.2.1 Normal Bulldozer Unit Layout

The various fire suppression agencies across Canada have prescribed similar organizational formats, which consist of two or more bulldozers followed or preceded by a combination of specialized crews and equipment. Under most conditions, such organizational structure has proven more effective than simpler formats.

The number of bulldozers to be used will vary depending on the size and quantity of fuel to be removed, the type of bulldozers available, and how efficiently they can perform in the given fuel type. This performance depends largely on the terrain, as well as on the soil and moisture conditions. Bulldozer units consisting of three properly selected machines have proven effective for most boreal forest types,

although the actual number of machines used will depend on the specific circumstances. Research studies have shown, however, that the production per bulldozer may decrease with an increase in the number of machines used.

Under boreal forest conditions, a degree of production may have to be sacrificed to maintain optimum efficiency and safety. Usually, a single bulldozer working alone is limited to very short jobs in settlement areas.

A single bulldozer frequently becomes stuck (Photo 1), or the operator is so wary of becoming stuck that only a limited fireguard is normally achieved. A two-dozer unit is not recommended for wetter soil types, since it is possible for both machines to become stuck simultaneously. Three bulldozers are manageable, whereas the use of more machines frequently leads to increasingly dangerous working conditions and reduced productivity (Photo 2).

A cat boss must assess each machine and operator as they arrive at the fire. The lead operator is usually the one with the greatest amount of fire experience, and is someone who operates a bulldozer capable of walking down timber at an acceptable pace. When dealing with mature forest cover-types, the lead bulldozer is generally the largest one in the unit. Its blade will be angled to ensure material is pushed away from the fire.

The blade of the second bulldozer will be angled similar to the lead bulldozer. This machine will be used for rough clean-up duties by removing brush and part of the organic layer, if required. The second and third bulldozer must synchronize their workload to avoid falling behind or having to wait.

The third bulldozer is used to complete the guard, which normally involves removing all organic material. Its blade is also angled away

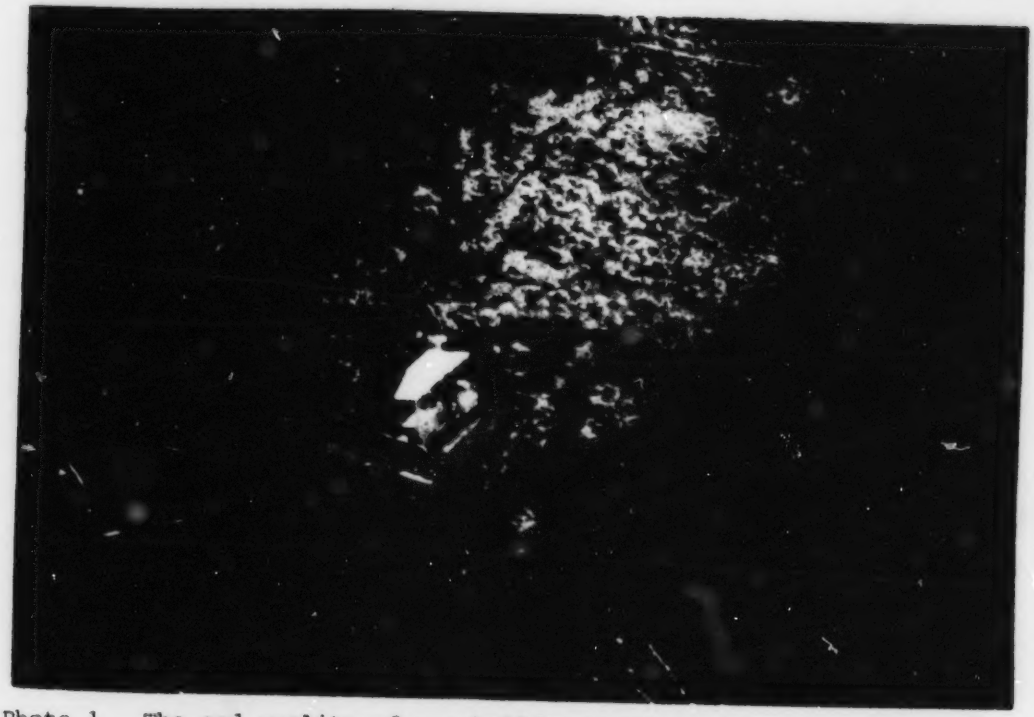


Photo 1. The sad reality of one bulldozer attempting to construct a fireguard.

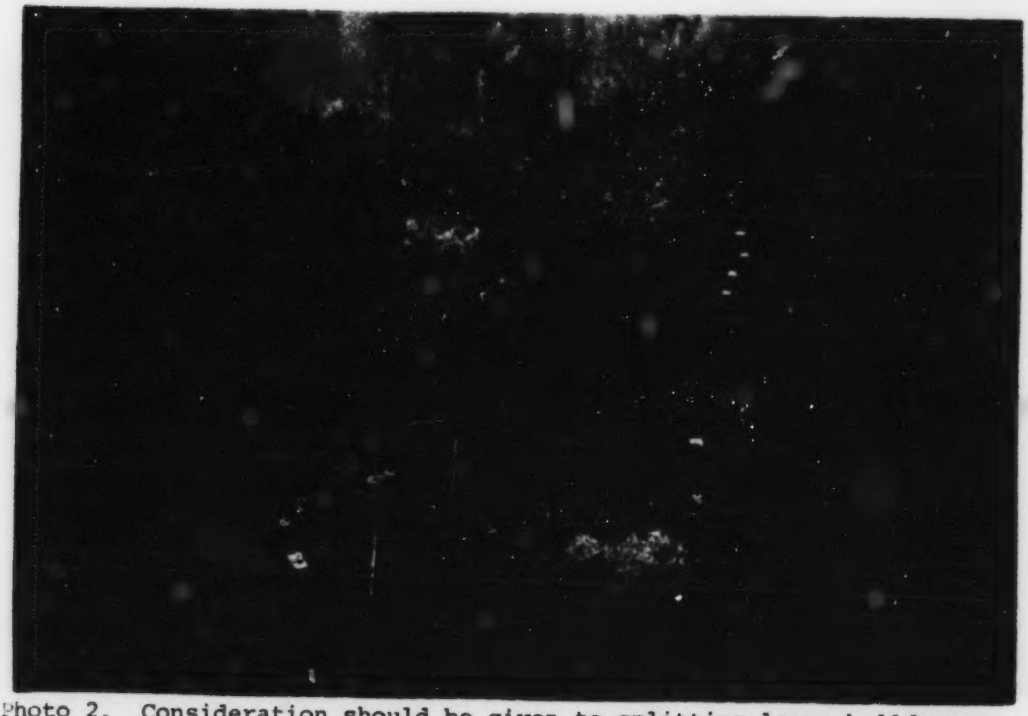


Photo 2. Consideration should be given to splitting large bulldozer units.

from the fire. In addition, this machine is normally used to construct seepage holes for backpack and power pumps when required, knock down snags and trees leaning toward the fireguard, and break up fuel accumulations that could provide an escape route for the fire.

2.2.2 Reclamation Awareness of Bulldozer Unit

Reclamation of the fireguard has become a major consideration for forest fire suppression personnel when initially assessing the fire. The need to construct an effective fireguard with minimal environmental damage and expense must prevail over simply extinguishing the fire.

A single bulldozer unit, consisting of six machines, has been used successfully. Three bulldozers, which are spaced a safe distance apart, walk down timber at a total width of two to three bulldozer blades. Care is taken not to push trees into standing timber. The three bulldozers that follow are used to clear all timber and organic material from the fire side of the line. The result is a fireguard approximately one blade wide on the fire side of the walked-down line, with all debris windrowed on the opposite side (Figure 1).

The main advantage of this type of unit is that debris can be rolled-back more easily during reclamation than with normal operations where the debris must be pulled out of standing timber. Although this method is best suited for unmerchantable stands, it does not receive unanimous recommendation regardless of circumstances.

2.3 Responsibilities of Bulldozer Unit Personnel

2.3.1 Line Scout (Line Locator)

On large fires, the line scout reports to the sector boss and normally does not operate a bulldozer. On smaller fires, however, or when direct attack methods are used, filling this position may be optional or the duties assumed by the cat boss. If parallel or indirect attack

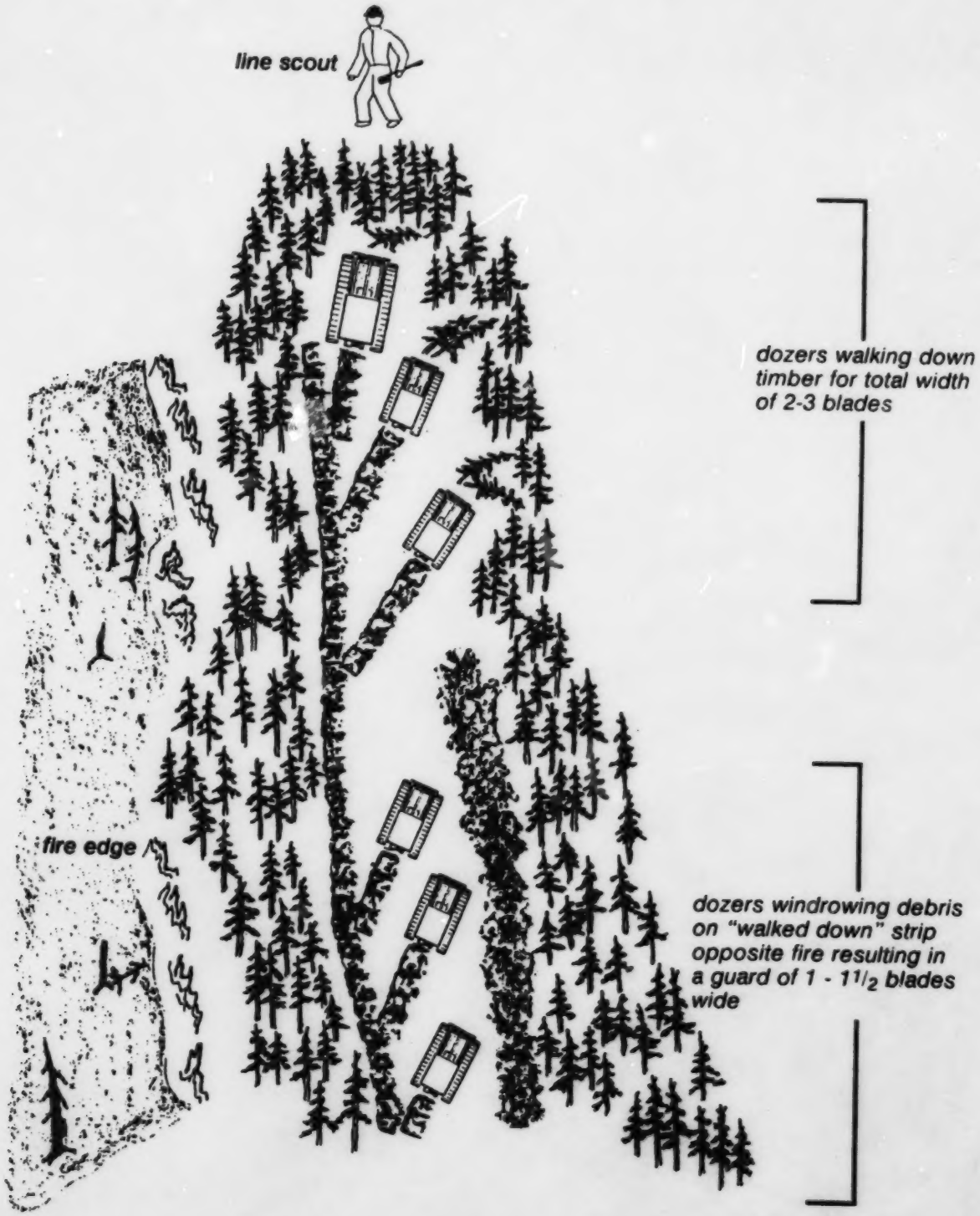

line scout
dozers walking down timber for total width of 2-3 blades
fire edge
dozers windrowing debris on "walked down" strip opposite fire resulting in a guard of 1 - 1 1/2 blades wide

Figure 1. Reclamation-conscious bulldozer unit.

methods are used, this position becomes vital and may even require an assistant. Therefore, the importance of having a qualified person to locate and mark line cannot be overemphasized. Qualifications for this position include the following:

- good physical condition (considerable walking/long work days);
- good understanding of fire behavior;
- extensive knowledge regarding bulldozer use and limitations; and
- sound knowledge of environmental concerns and reclamation practices.

When helicopters are available, this job can be simplified by making it possible for the line scout to search from the air for natural breaks, areas sensitive to disruption, creeks, and other beneficial or detrimental features. The line scout may want to land and examine specific locations more thoroughly. Once a route has been established, he can then walk back towards the bulldozers, locating and marking line as he goes. Or he may choose to return in the helicopter directly to the bulldozers, and work from that location forward.

The decision as to how far a line should be located ahead of the bulldozers will depend on the specific situation. A balance must be maintained between working a safe distance ahead of the lead bulldozer, but yet not laying out line that may burn over before the machines arrive. Some factors to consider when locating line include the following:

- time of day;
- current and anticipated fire behavior;
- current and anticipated weather conditions;
- topography; and
- forest cover-types.

Generally speaking, the line can be marked some distance ahead of the

unit when the movement of the fire is expected to be slow. A fire tends to move more slowly from evening to mid- or late morning, or when it is burning downhill or moving through aspen stands. When possible, it is advantageous to locate line for the night shift and have it walked down before darkness occurs. When a fire is expected to move rapidly, the line scout will work much closer to the bulldozer unit. A fire tends to spread more rapidly during the afternoon, when it is moving uphill, when fuel moisture decreases, when winds increase, when temperature increases or the relative humidity decreases.

When deciding how far to work ahead of the bulldozers, the line scout must keep himself informed of current weather reports and assess other contributing factors that affect the rate of fire spread.

2.3.2 Spotter

A spotter is required on fires where the line scout works well ahead of the bulldozer unit. Working a safe distance ahead of the lead bulldozer, this person establishes the final route from the one that had been roughed out previously by the line scout. This position is not required under all circumstances; the duties may be assumed by the line scout or cat boss, but only in those areas where the lead bulldozer operator requires additional help in determining the route. In the following situations, the lead operator frequently requires the assistance of a spotter:

- when walking down trees during night operations;
- in very dense brush; and
- in very wet areas where operators may require assistance to avoid becoming bogged down.

2.3.3 Swampers

Swampers are hired to assist bulldozer operators. The Workers Compensation Board requires that a swamper be present when a bulldozer is working alone in the forest; however, bulldozers seldom work alone

when constructing a fireguard. Good swampers have usually proven to be beneficial, while poorly trained swampers have proven to be a liability. Swampers can speed up the operation by performing such duties as helping change blade positions and handling winch cables. At all times, they must be aware of the hazards of working close to the bulldozers, and maintain a safe working distance between themselves and the bulldozers during actual winching operations.

2.3.4 Cat Boss (Bulldozer Foreman)

This position involves overseeing the entire bulldozer unit operation, including bulldozer operations, swamper and spotter positions, clean-up crews and burn-out crews. Usually the cat boss answers directly to the sector boss, but may answer to the fire boss or line boss depending on the manning level of the fire.

The cat boss is essential to the efficient operation of any bulldozer unit. This person should be well versed in all aspects of bulldozer use relative to fire suppression, reclamation obligations and agency policy. His duties include the following:

a. Upon arrival at the fire:
   - conducts mechanical inspections of all equipment;
   - assesses size of the bulldozer to determine its place in the unit;
   - assesses operators;
   - ensures safety equipment, such as canopies, lights and fire extinguishers, are serviceable;
   - informs all workers of their safety obligations;
   - makes arrangements for sleeping accommodations and meals; and
   - assigns bulldozer numbers.

b. Delegation of work:

   After receiving instructions from his immediate supervisor, the

cat boss briefs all members of the bulldozer unit on details of the action plan. He should ensure that each person or crew receives detailed instructions on safety, suppression objectives, environmental concerns, and the distribution and proper use of communications equipment.

c. Supervision of bulldozer unit:

- ensures that fireguard is constructed in accordance with the suppression plan, using acceptable methods and techniques;
- ensures that all work is conducted in accordance with safety standards, and should include two potential escape routes.
- ensures environmental disruption is kept to a minimum;
- replaces personnel who do not comply with work or safety ethics;
- keeps the immediate supervisor continually informed regarding progress;
- recommends changes to the original suppression plan or safety program when required;
- ensures worker morale remains at an acceptable level, and encourages constructive feedback from bulldozer operators, crew bosses, etc.; and
- authorizes and completes time records for all men and equipment in the unit.

2.4 Bulldozer Design Characteristics Beneficial to Boreal Forest Conditions

Bulldozer manufacturers have responded to the existing and potential northern markets by designing machines to overcome problems unique to boreal forest conditions. The work has been concentrated mainly on producing powerful, medium-sized bulldozers with increased flotation capabilities and ground clearance but without a significant sacrifice in traction and stability (Tables 1 and 2).

Table 1. Machine Weight and Net Horsepower For Various Dozers

SMALL DOZERS			MEDIUM DOZERS			LARGE DOZERS		
Model	Power KW	Net HP	Model	Power KW	Net HP	Model	Power KW	Net HP
D6C	89-104	120-140	D7F	134	180	D8K	224	300
D6D	104	140	D7G	149	200	D8L	250	335
Case 1450	104	140	TD-20E	157	210	TD-25E	231	310
TD-15C	104	140	TD-25C	213	285	TD-25G	239	320
JD850	104	145	D85A, E	134-164	180-220	D155A	239	320
JD850G	123	165	D-700	150	201	D-800	261	350
D60E	104-127	140-170	D-750	194	260	D9H	287	385
D65E	116-123	155-165	82-20B	153	205	D9L	343	460
M.F. 600C	107	144	82-30B	194	260	TD-40	335	460
D600D	107	144	82-40	205	275	D355A	306	410
HD11B	104	140	HD21B	204	273	D375A	383	508
HD14C	112	150	FD20	166	223	82-50	276	370

Table 2. Manufacturers' Designations

MANUFACTURER	PREFIX	EXAMPLES
Caterpillar	D	D7, D8K, D8L, D9G, D9H, D9K
International	TD	TD20, TD25B, TD25C
Fiat Allis (Allis Chalmers)	FD or HD	FD30, HD21C
Terex (Euclid)	C and TC (earlier models) number only (later models)	82-20B, 82-80
Komatsu	D (number and letter)	D120A, D150A, D355A
Case	number and letter	1450, 1150, 1150B
John Deere	JD number series	JD 450C, JD 750, JD 850
Massey Ferguson	MF number series	MFD 600C, MFD 700C

As a result of these design changes, the weight of the bulldozer is spread more evenly over a larger track covering the ground. Clearance has been improved by increasing the distance between the undercarriage of the bulldozer and the drawbar mechanism; this decreases the chance of the machine becoming hung up on stumps and rocks, or snagging brush and debris. These improvements also reduce environmental problems by minimizing disturbance to the soil surface and reducing the cutting of ruts into the ground. Such design features are reviewed in the following sections.

2.4.1 Wide Pad

Fitting standard bulldozers with wider than normal tracks was the first step in expanding the range of muskeg conditions in which bulldozers could work effectively. For work on soft ground, the flotation qualities and stability of bulldozers was increased to the point where fireguards could be constructed in previously unworkable conditions.

2.4.2 Extended Track

On low ground pressure (LGP) models, the length of the track was marginally extended and the neutral point was centered so that the weight of the bulldozer was spread more evenly over extra track; this resulted in better flotation. Low ground pressure bulldozers have proven extremely valuable, especially those in the 200 horsepower (hp) range that can work effectively in muskeg, mature white spruce, pine and aspen.

Critics of LGP models argue that the difference in performance between LGPs and ordinary wide pads is marginal. Undoubtedly, there is some merit to this concern, but similar distress regarding wide pads was voiced approximately 20 years ago. Selecting a bulldozer, therefore, must be based largely on personal preference and the intended use of the machine. Experience and discretion on the part of the bulldozer foreman and lead operator is essential in machine selection.

2.4.3 Elevated Sprocket

The elevated sprocket, or suspended undercarriage, allows the track to conform more readily to uneven ground surfaces. The rear sprocket governs the location of the rear of the track, and consequently influences the center of balance. The Caterpillar "Low Ground Pressure" model is designed primarily for bulldozer work, while the "Logging and Petroleum Special" is designed primarily for winching. This difference in ability is achieved by simply altering the center of balance. Suspended undercarriages have basically been confined to medium-sized bulldozers (D6s and D7s).

2.4.4 Fire Suppression System

This system is designed to extinguish fires, originating from hot diesel, oil, wood particles, leaves and other debris, that have started near the motor of the bulldozer. This system is recommended for hostile work environments, such as forest fires, and can be either activated manually or set to respond automatically.

2.4.5 Special Track Shoes Designed for Muskeg

Various types of track designs are being tested to determine their suitability for different muskeg types. Komatsu has introduced a self-cleaning circular arc shoe that is designed to increase traction and maneuverability over soft terrain. This equipment is supposed to minimize damage to the ground, thereby increasing the amount of traffic that an area can sustain.

3.0 BULLDOZER FIREGUARD CONSTRUCTION PRODUCTIVITY

3.1 Results of Previous Productivity Studies

Previously, most productivity studies done on bulldozer fireguards were conducted in the U.S., and thus bear little resemblance to boreal forest conditions. However, a pilot study was conducted by the

Canadian Forest Service during the 1970s. Most of the data for this study was collected during spring campaign fires when it was more difficult to construct bulldozer fireguards. Despite this fact, it was possible to establish applicable resistance classes and production rates for a number of fuel types.

During this study, an attempt was made to determine the types, sizes and number of bulldozers per unit that were best suited for constructing fireguards in different types of timber. Further, any aspects of the total operation that appeared to affect efficiency were identified. The factors affecting development of bulldozer fireguards in boreal forest fuel types differed substantially from those in other forest regions where the influence of soil and moisture conditions were less significant.

In most forested areas, productivity correlates directly with the amount of material to be removed and the horsepower of the bulldozers. In contrast, work occurring under boreal forest conditions is more affected by how well the bulldozers can perform under adverse soil and moisture conditions. Research data from other studies have shown that production per bulldozer decreases as the number of bulldozers per unit increases. However, this theory cannot be applied to normal boreal forest conditions since the chance of bulldozers becoming stuck is much greater here than in other forest regions. Therefore, a bulldozer unit consisting of two or more medium-sized bulldozers with good flotation capabilities, is recommended for a variety of boreal forest fuel types. Three bulldozers per unit has proven to yield a good balance between productivity, operational efficiency and safety requirements (Figure 2).

3.2 Manpower Versus Bulldozers

Firelines constructed by crews using hand-tools are generally confined to the following: very small fires; sections of larger fires where

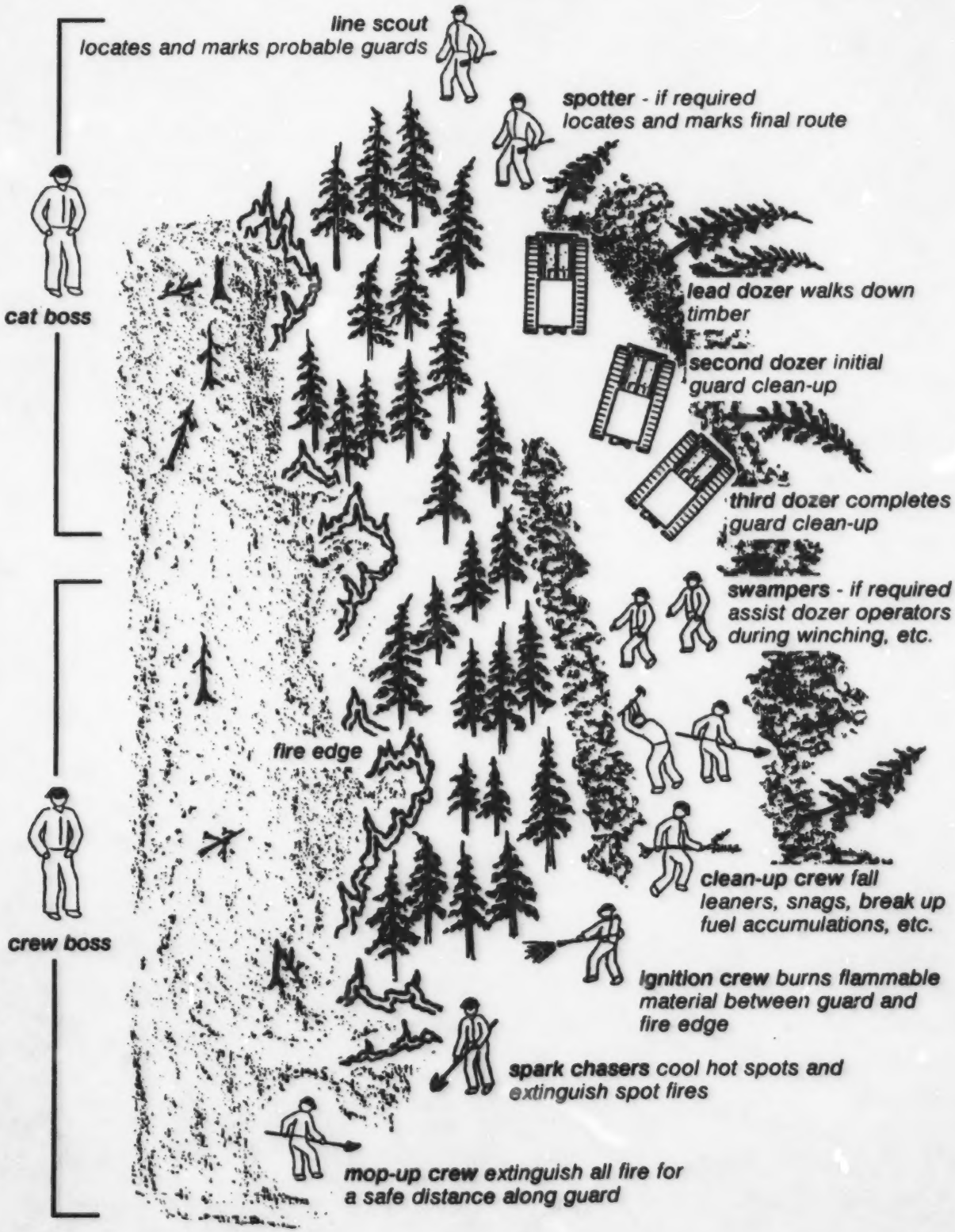

line scout
locates and marks probable guards
spotter - if required
locates and marks final route
cat boss
lead dozer walks down timber
second dozer initial guard clean-up
third dozer completes guard clean-up
swampers - if required
assist dozer operators during winching, etc.
fire edge
crew boss
clean-up crew fall leaners, snags, break up fuel accumulations, etc.
ignition crew burns flammable material between guard and fire edge
spark chasers cool hot spots and extinguish spot fires
mop-up crew extinguish all fire for a safe distance along guard

Figure 2. Typical three-dozer unit complete with support personnel

bulldozers cannot work effectively (wet, rocky or steep areas); or areas of environmental concern. As well, large quantities of hand-built fireguard (handline) are constructed in the more remote areas where distance to the fire or adverse ground conditions make the use of bulldozers impractical. Handline can be constructed for a maximum of one hour at a rate of approximately 40 m/man-hour in pine, and 20 m/man-hour in aspen, white spruce, black spruce and slash. Production rates for sustained work (up to eight hours) would be approximately half that of the initial one-hour value.

On the other hand, however, "hot-spotting" is often a more viable alternative to bulldozer line construction on small fires or sections of larger fires. Initial results from a productivity study have shown that one man can contain 100 m to 400 m of fire-perimeter per hour on surface fires of low and moderate intensity that occur in black spruce and jack pine. However, these initial attack rates could probably not be sustained for more than 15 to 30 minutes. Depending on the intensity of heat, smoke and ambient temperature, production rates for longer periods would be much lower, perhaps 20 to 70 m/man-hour.

Therefore, it would be impractical to extend handline or hot-spotting operations over a 10- or 12-hour day, whereas patrol or mop-up activities can be sustained over that length of time. A realistic approach could involve having crews perform the more physically demanding work first, then switching them to less demanding activities before they become critically fatigued. Fatigue studies have shown that the rate of production drops dramatically after approximately five hours under extremely adverse conditions. Furthermore, the smoke released when certain vegetation is burned (e.g., Labrador tea) is an irritant to firefighters and cannot be tolerated for extended periods.

3.3 Fuel Resistance to Bulldozer Fireguard Construction

The size, quantity and type of flammable material to be removed, and

the difficulties encountered in moving these fuels, will have a major effect on the speed and ease with which an adequate guard can be constructed. Contributing factors include the following:

a. Upper story
   - size;
   - density;
   - rooting habit;
   - wood characteristics; and
   - snags.

b. Understory
   - size;
   - density;
   - rooting habit; and
   - down material.

c. Soil
   - depth of organic layer;
   - moisture regime;
   - frost; and
   - rocks.

d. Topography
   - slope (up, down, side, degree, aspect);
   - Continuity of topographical types; and
   - creeks, muskeg, etc.

3.4 Resistance to Fireguard Construction Classes

The effect and degree of resistance of the foregoing are fairly self-explanatory, but they will be discussed in greater detail in the following sections as they apply to individual fuel types.

Forest fuels are classified according to the degree of resistance to fireguard construction. The number and variation of different fuel types makes classification impossible to generalize for all conditions. However, the more common fuel types have been classified according to their resistance to bulldozer fireguard construction. These are detailed below:

3.4.1 Low Resistance

- range types, grasses and other large openings where the organic layer does not exceed 12 cm, and where soil moisture is not detrimental to fireguard construction;
- open and fully stocked pine stands having less than 8 cm of organic material;
- pine regeneration if stumps and windfall do not significantly affect production;
- open muskeg types where the frost layer is strong enough to support the weight of the bulldozers, and where a satisfactory "track guard" results from simply walking the bulldozers over the muskeg or a fireguard can be constructed by skimming a thin layer of organic material from the surface; and
- young, open aspen stands where the organic layer does not exceed 10 cm.

3.4.2 Moderate Resistance

- range types, grasses and other openings where the organic layer exceeds 12 cm, or where the organic layer is less than 12 cm and soil conditions marginally reduce productivity;
- dense, mature pine stands or where the organic layer exceeds 8 cm;
- young, open white spruce stands where the organic layer does not exceed 12 cm and moisture conditions do not retard productivity;
- most immature aspen stands;
- slash blocks where the organic layer does not exceed 12 cm and

removal of stumps does not greatly slow production; and

- open black spruce stands where a shallow guard will be effective and the frost is adequate to support the weight of the bulldozers.

3.4.3 High Resistance

- most recently cut black and white spruce cutover blocks;
- most white spruce height and density classes;
- most black spruce stands that are in a relatively shallow organic layer, and where the bulldozer can work on the frost layer most of the time; and
- most mature aspen stands.

3.4.4 Extreme Resistance

- most muskeg types when frost is absent;
- clearcuts that have a large volume of slash, a deep organic layer, are very wet or where stump removal is very difficult;
- dense, mature white spruce stands; and
- mature or overmature aspen stands.

3.5 Bulldozer Productivity

Results of the NOFC study show that there are significant differences in production between fuel types and the type of bulldozers used. A rate of 40 m/dozer-hour was observed with two D6s working in a B3SwA stand (Table 3). This contrasted with two D8s constructing 1200 m/dozer-hour of fireguard in mature pine. However, if the two D6s produced only 40 m of fireguard because of soil and moisture conditions, the D8s might have produced even less or none at all in this particular B3SwA stand because the machines were more prone to becoming stuck.

Calculated production rates were based on actual working time while the bulldozers were constructing the fireguard (Figure 3). Productive

Table 3. Summary of NOFC Bulldozer Fireguard Productivity Study

BULLDOZERS	TOTAL TIME	PRODUCTIVE TIME	COVER TYPES	METRES PER 100 NET HP/HR
3-D6		0.50	Old burn	616
1-D6	5.00	5.00	B1P1	556
1-D4 (1)	39.00	2.50	B1A Slash	503
3-D6		2.00	Sw & Sb	472
1-D8	1.00	1.00	C2SsP1	425
1-D8	4.00	4.00	B1P1	351
1-D8		1.00	B1P1	340
2-D8, 1-D7, 2-D6 (5)	21.00	15.00	A1ASw	280
1-D7, D17A, 1-D6WP (2)	15.00	14.06	B2P1Sw	223
2-D6, 2-D7 (4)	0.16	0.16	B2SwFb	202
1-D8		1.00	B1P1Sw	170
2-D8, 2-D6, 1-TD15 (5)	10.00	6.00	A1Pj & A1Sb	145
2-D8, 2-D6, 1-TD15 (5)	12.50	5.00	B1SbPj & C2SbPj	145
1-D7, 2-D8, 1-D6 (4)	6.50	6.00	C2PJ (180 Chns.) C1A (100 Chns.) C3SwA (40 Chns.)	143
2-D6, KUM (60A & 60E) (4)	0.33	0.33	B2SwFb	142
3-D6		2.50	Sw & Sb	136
1-D7, 5-D6 (6)	2.25	1.75	C2Sb	123
1-D8	4.00	4.00	C2SsP1	111
1-D8, 1-D7, 2-D6 WP (4)	14.30	9.00	C3Sb & C3Sw	109
1-D7E, 1-D4 (2)	2.34	2.17	A2Fb	102
4-D7, 3-D6 (7)	18.00	10.00	B2SbA	93
4-D7, 3-D6 (7)	18.00	9.00	C2Sb	82
1-D6, 1-D7 (2)	5.00	4.00	B3P1 & B2ySb	72
1-17A, 1-D6WP (2)	14.30	6.00	B4Sw	70
5-D7, 3-D6 (8)	14.00	11.00	C2YSw	69
3-D6 (3)	5.00	3.89	B4Sw	67
1-D8H36A, 2-D6C (3)	12.50	10.00	B2ySb	64
4-D7, 3-D6 (7)	14.00	7.00	C2ySb	60
4-D7, 2-D6 (6)	14.00	9.50	C2ySw	59
5-D7, 3-D6 (8)	18.00	9.00	C3Sw & C2xSb	59
1-D8H, 1-D7, 1-D6 (3)	9.00	5.00	B3SwA	59
1-8280, 1-D7E, 1-D6 (3)	9.00	6.00		57
1-D8, 2-D6 (3)	12.50	9.66	B3P1 & B2ySb	53
1-17A, 1-D6WP (2)	14.30	9.00	B3SwPjA	53
1-D8H, 1-D7, 1-D6 (3)	7.30	2.00	A1SbSw	50
2-D8, 1-D7, 2-D6 (5)	126.00	75.00	C3SwA	50
1-D6, 1-D7 (2)	12.00	9.00	C3ASw	43
2-D7, 2-D6 (4)	7.00	5.00	C2xA	33
1-D7, 5-D6 (6)	14.00	10.00	A1Sw	33
5-D7, 3-D6 (8)	18.00	10.00	B2xASw (60%) B2yPSw (40%)	33
1-D6, 1-KUMS, 60E (2)	14.30	9.00	B4Sw	31
1-D8, 1-D7, 2-D6 (4)	14.30	11.00	B4Sw	28
2-D8, 1-D7 (3)	5.00	4.25	C3FbA	25
1-D6, 1-KUMS, 60E (2)	14.30	9.00	B3SwA	25
1-D8, 1-D6WP, 1-17A (3)	14.30	9.00	B4Sw	21
1-D8, 1-D846A, 2-717A, 2-D6, 1-D4 (6)	52.00	31.00	A2SbP1A (P1A on Ridge)	13

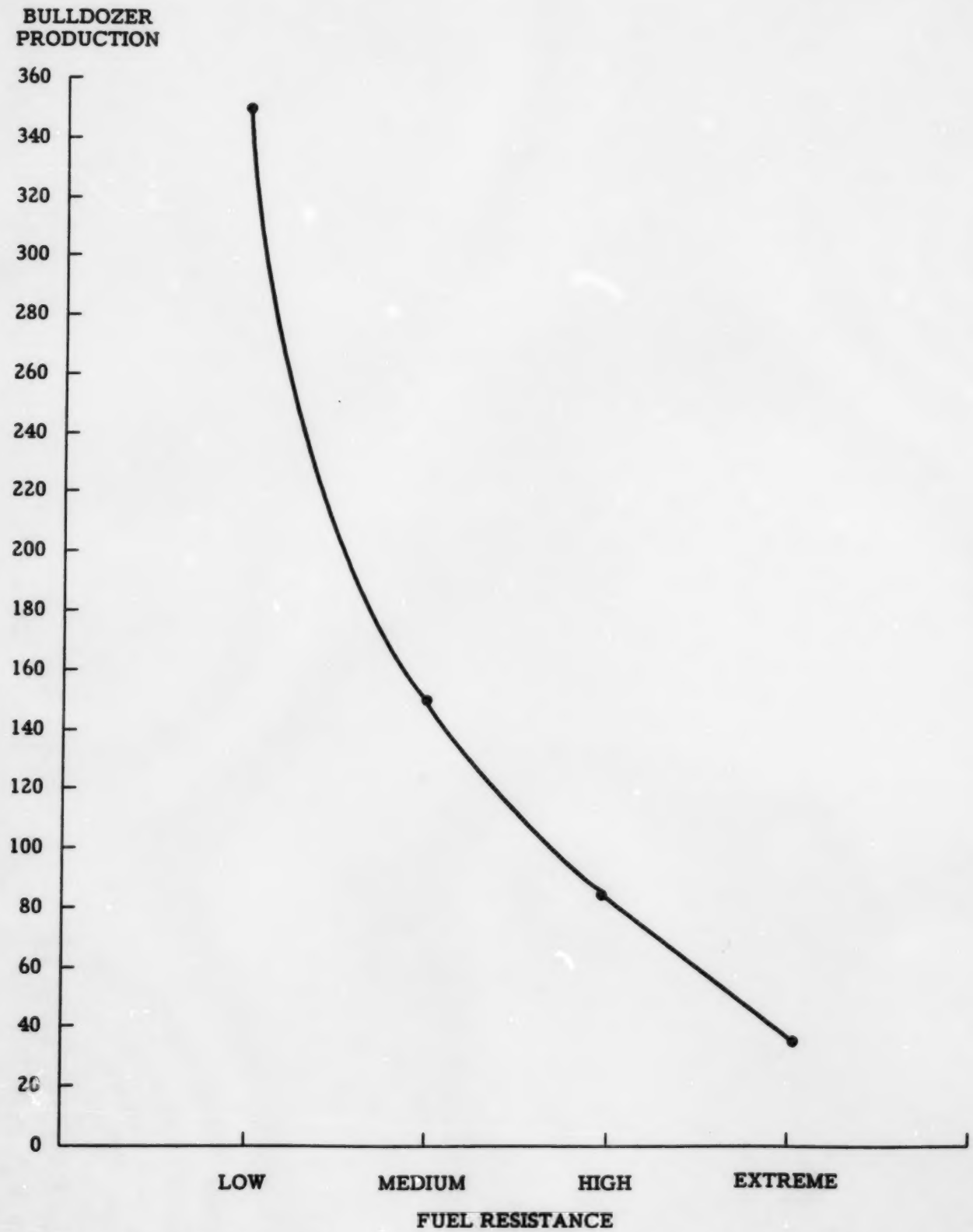


Figure 3. Bulldozer productivity as a function of fuel resistance (m/100 horsepower/hour).

construction accounted for only 60 percent of the total time for which the bulldozers were being paid. The remaining 40 percent of the time, the bulldozers were restricted for various reasons; for example, conditions were unsafe to proceed with construction, machines were stuck, downtime for repair and service, and waiting time before remaining bulldozers arrived to make up the units.

While fuel resistance to line construction is similar for both bulldozers and handline crews, differences do exist. Bulldozers are more affected by the ability of the ground surface to support the weight of the machines. Table 3 shows the significant variations occurring between types of bulldozers and within various fuel types. Fuel types where soil moisture and frost have a major effect on production are also the most difficult to estimate. For example, the presence and amount of frost may be the determining factors when deciding if a specific black spruce type will fall into the moderate, high or extreme resistance class.

3.6 Estimating Productivity

A relatively simple method for estimating bulldozer fireguard productivity is currently being evaluated in the field (Tables 4 and 5). These tables are not intended to provide accurate rates under all circumstances, but rather to assist field personnel in determining the number and size of bulldozers required to complete a given section of fireguard within a specific time frame. Further assessment may determine that these tables have to be adjusted to accommodate local conditions.

Productivity is determined primarily by height, density and cover-type of the particular stands. The basic rate noted in the table may then be adjusted for such factors as:

- number of helicopter landing pads required;
- night operations (if applicable);

Table 4. Bulldozer Fireguard Productivity By Resistance Class

RESISTANCE CLASS	COVER TYPES	METRES/100 NET HORSEPOWER/HOUR
LOW	PlPj (immature, mature)	416
	PlSb[1] (immature)	268
MODERATE	PlSw (immature)	196
	SwFb (immature)	172
	PjSb[1] (immature)	145
	SbPj[1] (immature)	145
	Sw (immature)	109
HIGH	SbA[2] (immature)	93
	Fb (mature)	64
	PjASw (mature)	96
	PlSb[2] (mature)	63
	Sb[2] (mature)	79
	Sw (mature)	79
EXTREME	SwA, SwPjA, SwSb[3] (mature)	57
	ASw-SwA (mature)	34
	A Slash	57
	Sb[3] (immature, mature)	13
	Sw (mature)	43
	A (mature)	

[1]Adequate frost to carry dozers

[2]Some frost - will not carry dozers continuously

[3]No frost

Table 5. Bulldozer Fireguard Productivity (Meters Per 100 Net Horsepower/Hour)
1. Basic table rate

DENSITY CLASS	INDEX (METRES)	HEIGHT CLASS	INDEX (METRES)	COVER TYPE	INDEX (METRES)
A	80	1	140	Pine	160
B	40	2	80	Aspen	60
C	25	3	30	Sw-Frost	40
D	10	4	10	Sw-No-Frost	30
				Sb-Frost	20
				Sb-No-Frost	*
				Clearcuts	**

* 30% of Sb-Frost rate
** 150% of original type

2. Adjustment Factors

a. Helispot construction - 1 hour per helispot
b. Nighttime - 80% of daytime rate
c1. Initial attack - productive time averages 90% of total time
c2. Campaign fires - productive time averages 70% of total time
d. Excessive windfall - 75% of original rate
e. Effect of slope expressed as a percentage of production on the level

+30	20	10	0	10	20	-30
50%	65%	80%	100%	115%	125%	115%

3. Instructions

Calculate productivity in metres per 100 net horsepower per hour by adding the index values for density, height and cover type. The rate can then be adjusted for initial attack, campaign fires, night construction, windfall and number of helispots.

The above index is based on dozer units consisting of 3 properly selected dozers.

4. Example

C2A type: 25 + 80 + 60 = 165 m
Initial attack: 90% of 165 = 148 m
Night operation: 80% of 148 = 118 m
Windfall, Slope — no effect
*4.8 (horsepower) x 118 = 556 m per hr.
1 helispot is required every kilometre

* Dozers consist of 2-D6s and 1-D7 or 480 net horsepower

This unit could complete 371 m per hr. or approximately 1 km every 3 hr. c/w helispot

1 chain = 20 metres

- initial attack or campaign fire production;
- excessive windfall (if applicable); and
- slope.

Because of the wide range of bulldozer horsepower ratings, production is estimated in metres per 100 net horsepower, rather than in metres per dozer-hour.

4.0 BULLDOZER REQUIREMENTS FOR INDIVIDUAL BOREAL FOREST TYPES

4.1 Fuel Resistance

4.1.1 Black Spruce

Results from the NOFC study showed that black spruce (Sb) was usually classified as having high or extreme resistance to fireguard development. However, on some spring fires where the frost layer was sufficiently strong to support the weight of the bulldozers, a fireguard could be constructed quite rapidly through sparse black spruce types with only moderate resistance.

Occasionally an adequate line can be constructed through very wet areas by simply walking the bulldozer across the muskeg with the blade in an upright position, or by pushing just enough material with the blade to make the bulldozer spin, resulting in deep tracks that usually fill with water. In general, bulldozers that have good flotation ability (140-225 hp), and are equipped with wide pads or extended tracks are the bulldozers best suited to black spruce and other muskeg types.

Most experienced cat bosses prefer to have at least three bulldozers with winches per bulldozer unit; this keeps stuck time to a minimum while maintaining acceptable production levels.

It is neither necessary nor practical to remove all organic material

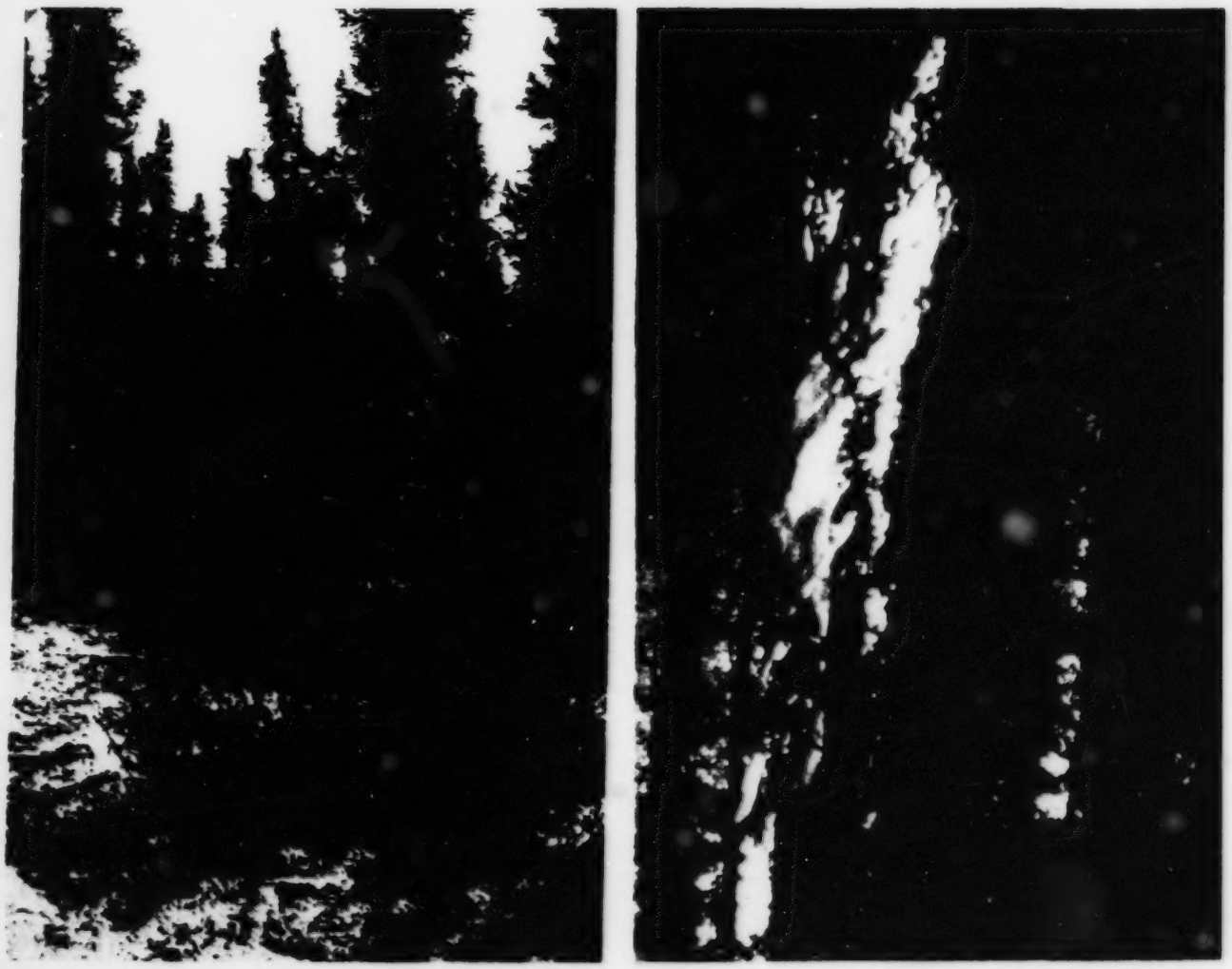
under all conditions, since this layer may exceed 30 cm. Moisture will often seep into the depression that remains after a fireguard is created, keeping the surface wet enough to prevent the fire from burning across the fireguard. However, if moisture does not mix with the organic layer, a few hours of sunlight can dry out the organic layer enough to allow the fire to cross the guard. It is, therefore, necessary to have crews patrol such lines.

Sector bosses and cat bosses must be adaptable when working under adverse conditions, and remain open to alternative techniques (Photos 3a, 3b). If moisture and soil conditions prevent acceptable bulldozer fireguard construction rates from being achieved, hot-spotting crews, bombers, etc., may have to be used instead. The bulldozers are then usually walked around the muskeg to continue guard construction in the next forest-cover type.

Discretion is urged when crossing muskeg with bulldozers. If frost is absent, the normal crossing procedure involves traveling quite fast and avoiding unnecessary use of steering clutches to prevent tearing through the rooted surface layer. High speed travel appears to work well when the muskeg is relatively smooth. However, speed should be reduced when traveling over hummocks to prevent the front end from coming down with an impact sufficient to break through the surface. Bulldozers can be difficult to winch if they become stuck in muskeg, since they are usually suspended from the blade which tends to pull a large amount of material as they are being winched backward. When possible, muskegs should be skirted.

4.1.2 Slash

Results from the NOFC bulldozer study indicate that slash blocks are normally in the low-to-high "resistance to bulldozer fireguard construction" categories. Many of the same resistance factors found in dealing with the original cover remain after clear-cutting. These include soil, topography, size and density of vegetation, and plant



Photos 3a and 3b. A bulldozer fireguard is normally difficult to construct in black spruce. In addition, "torching-out" and crowning can occur at lower fire hazard levels than with other boreal forest cover types.

rooting habits associated with the original cover type.

Stumps are difficult to remove for several years following cutting, and usually require a 200-hp lead bulldozer. Some factors resulting from clear-cutting, that contribute to the difficulty level of fireguard construction, include the following: elapsed time since clear-cutting occurred; quantity of material left behind; regeneration and secondary growth; and the existence of skid trails and roads.

The combination of these factors determines the number, size and types of bulldozers that will be required. Productivity can be increased substantially by using skid trails, logging roads and landings. Large stumps may have to be avoided to maintain a good production level. Several lead operators have mentioned the mistake of assuming clearcuts are wetter than they appear. In fact, they may be drier than the surrounding stands for a short period in the spring since moisture loss from evaporation increases significantly after the stand has been removed; however, water loss from transpiration virtually stops after cutting and the overall moisture regime is usually similar or even wetter than before clear-cutting occurred.

4.1.3 Aspen

Generally, aspen (A) stands are considered ideal for reducing the speed of a fire, whose spread is relatively slow through these stands and confined to the surface, except for a few days in spring when leaves are just emerging. Following leaf emergence and "greening up" of minor vegetation, pure aspen stands can often serve as natural fire breaks, except during periods of extreme fire hazard and/or high winds.

Hot-spotting crews can usually contain fires in aspen during midsummer without great difficulty. If bulldozers are available, however, it is normally easier and less risky to construct a bulldozer fireguard through the stand and use the men for burning out and patrolling more

hazardous fuel types.

Despite the fact that soil conditions in aspen stands are generally quite favorable for bulldozer operation, production is normally quite low (see Table 3). It is usually necessary for the lead machine to remove a few centimetres of soil in order to cut off young aspen saplings. The saplings' flexibility allows them to bend forward as the blade passes over, and then to snap back to an upright position if some topsoil is not also removed. Depth of organic material varies between stands, but it is normally from 10 cm to 15 cm.

In comparison to other boreal forest species, mature aspen are difficult to push over because of their large tap root system. A lead bulldozer, having at least 200 hp (net) is recommended. Smaller bulldozers can leave problems for the clean-up bulldozer, since larger aspen tend to break off above ground rather than being pushed over with the stump and roots intact. Frequently, one clean-up bulldozer can remove all organic material without great difficulty. In mature open stands, the line scout should consider constructing a fireguard around and between large trees where possible, even though it may make the line slightly longer.

Because of their crown structure, fallen aspen frequently cause problems by hanging up in the crowns of standing trees. Despite the problems and additional time it might take, for obvious safety reasons these trees must be knocked down as construction progresses on the fireguard. The underbrush common in aspen stands is usually more of a nuisance than a serious resistance factor.

The direct attack method is well suited to most fires burning through aspen, since fire intensity is usually low with a slow rate of spread. A fireguard with a maximum width of one bulldozer blade is usually adequate for fires in aspen. If appropriate, a narrower guard can be constructed by tilting the blade to create a guard less than one blade

wide.

4.1.4 Jack/Lodgepole Pine

Normally, pine (Pj, Pl) species offer less resistance to bulldozer fireline construction than do most other major boreal forest species. Most can be pushed over without great difficulty (with the exception of very large pines), since the sandy subsoil provides excellent traction for the bulldozers. As well, only limited quantities of organic material have to be removed, and time delays are usually minimal.

Smaller bulldozers (D6s) are probably large enough to be used as lead bulldozers for immature pine species. However, a D7 or D8 is recommended for very large pine. If continuous pine stands are encountered, the cat boss may want to take advantage of larger bulldozers but in smaller bulldozer units (i.e., two D8s). In short, young pine stands permit greater versatility when selecting bulldozer sizes and types. If low areas or creeks are encountered, a minimum of two bulldozers should be used.

Young pine trees that may have developed after a fire can be growing up through a large quantity of windfall, thus slowing production. "Case hardened" snags also tend to slow production since operators must be alert to prevent broken tops from falling onto the bulldozer. Another safety concern is the potential for flare-ups and crown fires that can occur quickly and without warning. This may be sufficient reason to maintain units consisting of at least two bulldozers; having these machines on standby helps to relax people so they are less apt to panic if an emergency should occur.

Because pine stands normally grow on sandy subsoil, forest officers must be aware of the potential for erosion gullies to form. Firelines should not be constructed straight up and down steep slopes. As well, bulldozer operators may remove more soil than is necessary since the

duff layer is usually less than 8 cm deep.

4.1.5 White Spruce

White spruce (Sw) stands are normally in the high to extreme resistance to bulldozer fireline construction categories (see Table 4) depending on height, density, soil condition, moisture regime and topography. Immature white spruce are pushed over quite easily; mature trees present some difficulty for smaller bulldozers (D6s). Moisture conditions and depth of organic matter (averaging approximately 15 cm deep) can vary dramatically between stands and within stands.

The southern and central portions of the boreal forest region are very susceptible to erratic spring fire occurrence and behavior. During spring, the presence or absence of frost is of the utmost importance when predicting productivity or selecting bulldozers.

A bulldozer unit consisting of three medium-sized bulldozers with good flotation capabilities has been used with excellent results for most boreal forest types. In immature Sw stands, a 150-hp lead bulldozer is adequate, while a 200-hp lead bulldozer is recommended for mature stands. Low ground pressure per unit area, high ground clearance and high blade lift capability may be of importance when encountering adverse ground conditions. Low ground pressure D7s or equivalent machines probably best meet this criteria.

The arrangement of bulldozers within a unit may depend on prevailing conditions. For example, if a cat boss has one D7 (LGP) and two D6 wide pads, the arrangement of bulldozers may be different for immature versus mature Sw stands. Arrangement in immature Sw stands may be D6 lead, D7 second and D6 clean-up, as opposed to a D7 lead followed by two D6s for mature Sw stands. Unless the cat boss has extensive fire experience, the arrangement may be best left to the operators.

5.0 BULLDOZER STRATEGY

5.1 Preconstruction Analysis

If a fire is to be brought under control, the total fire suppression effort in containing the fire perimeter must be greater than the increase in fire perimeter caused by the fire spreading. This difference will ultimately determine how quickly the fire is brought to the state of being held and also determine the final size of the fire. If the suppression plan includes bulldozer fireline construction, several basic questions and points must be considered.

5.1.1 Fireline Location

- How close to the edge of the fire can the fireguard be constructed? Firelines should be as short as possible, and under normal circumstances be as close to the edge of the fire as possible.
- Can natural breaks or previously constructed barriers, such as seismic lines, be used?
- Where can the line be constructed with the least amount of environmental disruption?
- Can topographical features be used for subsequent burn-out (i.e., crest of hills opposite the fire)?
- The fireline should be located where there is the least potential for fuel to be added to the fire. Avoid constructing a line on steep slopes above a fire.
- Can escape routes be used immediately should a blowup occur?

5.1.2 Numbers, Sizes and Types of Bulldozers

- Determine the minimum horsepower requirements for the lead bulldozer under the most difficult forest types that will be encountered.
- Are LGP or wide-pad machines required?
- The operator of the lead bulldozer, which normally is the largest

machine, should have extensive fire and bulldozer experience, since he will be setting the pace for fireguard construction, as well as following the line marked previously by the line scout.

- Will existing roads, bridges and terrain support the weight of the desired machines?

5.1.3 Required Width of Fireguard

- The width of the fireguard should correlate with the expected intensity of the fire along the fireguard, whether from the fire itself or as a result of burning out.
- Fireguard construction should add as little fuel to the fire as possible.
- The wider the fireguard, the more debris created; this results in less production and more reclamation work.

5.2 Bulldozer Attack Techniques

The method used, or more often the combination of methods, will depend on present fire behavior, anticipated fire behavior, and the specific fireline tactics mentioned previously. Normally, fires are contained using the direct and parallel techniques; i.e., constructing a fireguard around the rear and flanks to eventually pinch in on the head of the fire, and completing a guard across the head of the fire (Figure 4).

5.2.1 Direct Attack Method

The direct attack method means literally attacking the fire's edge, or constructing a fireguard very close to the edge (within approximately 10 m) in an effort to contain the fire. This method is normally restricted to cooler burning fires where heat and smoke are not too intense for the fire crews. It can also be used on small, hot-burning spot fires or sections of fires where further spread must be stopped immediately. The type of direct attack used is distinguished by where the debris is pushed (Photo 4).

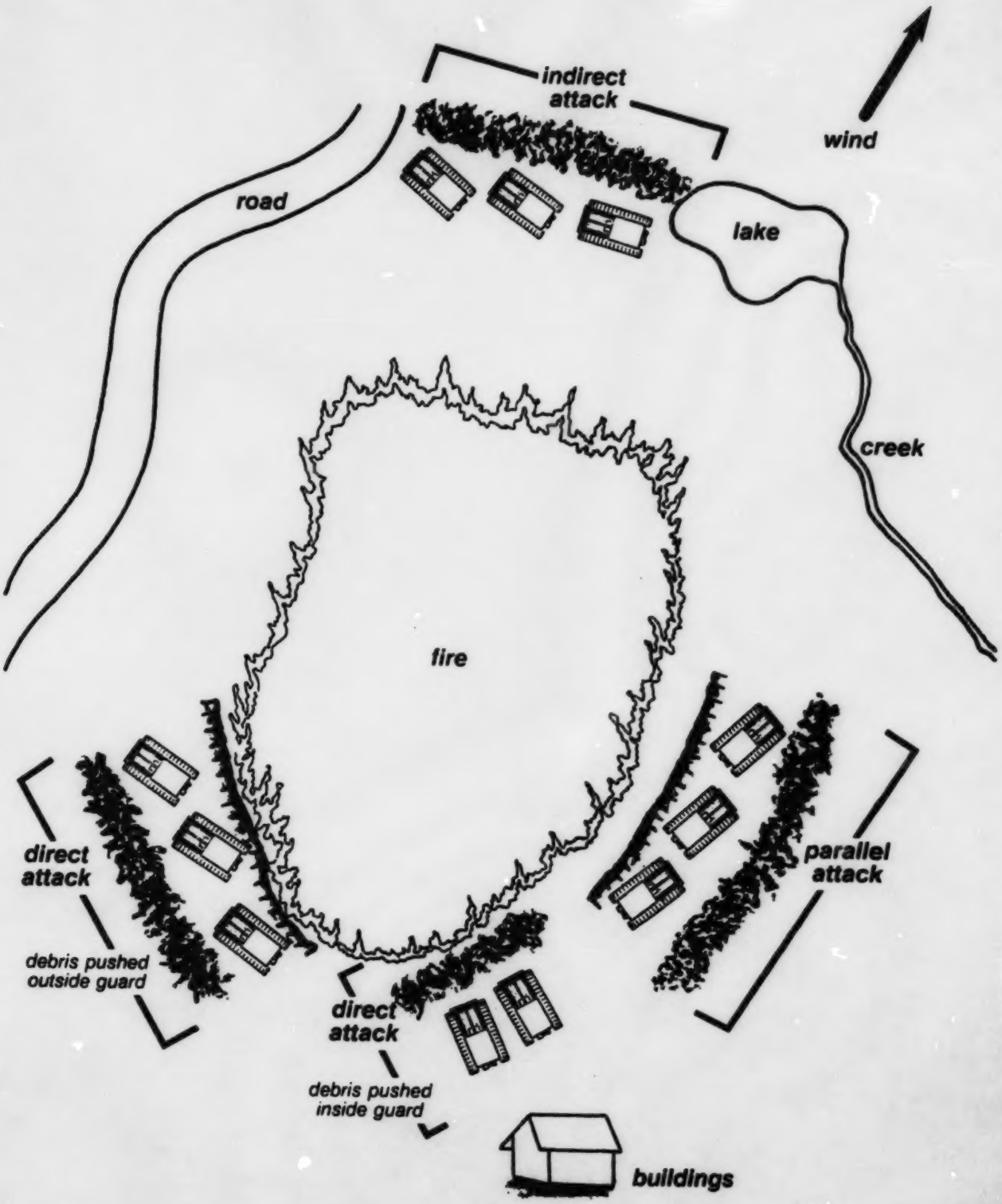


Figure 4. Attack methods

a. Direct Attack -- Debris Pushed Towards Fire

This method should be considered only in urgent situations when other methods are considered to be impractical. The addition of debris to the fire increases the intensity of the fire, possibly creating convection columns that may cause spotting, thus generally complicating both patrol and mop-up activities. Some circumstances where this method could be used effectively include the following:

- small lightning strikes;
- spot fires outside the fireline;
- as part of a desperate attempt to save buildings or other man-made structures; or
- if a section of fire is just about to enter an extremely flammable fuel type.

The primary objective is to push all flammable material together with as much mineral soil as is required to smother the flames and stop spotting. In this case, the bulldozer operator works at right angles to the fire, pushing a mixture of nonflammable and flammable material into the fire. This method can be supported by helitanker support to cool the fire enough to allow the bulldozer to work close to the edge of the fire.

While this technique accomplishes the primary objective of stopping the spread of the fire, it will require extensive patrolling since the fire can continue to burn and smolder for days or weeks. The bulldozed piles must be torn apart eventually and wetted down.

b. Direct Attack -- Debris Pushed Away From Fire

This method of attack is most often used in conjunction with the parallel attack method on the cooler, slower-moving

sections of larger fires. It is commonly used along the rear and flanks of a fire, and can be supported effectively by airtankers and helitankers to cool any hot sections (Photo 5).

When using this method, bulldozer operators work close to the fire, pushing all debris away from it. This work requires a concentrated effort on the part of the operators to maintain a distance of a few metres from the edge of the fire, thus eliminating any chance of burning material being pushed outside the guard. The few metres of unburned fuel lying between the edge of the fire and the fireguard should be burned out.

Bulldozer operators should break up any larger accumulations of fuel that remain inside the guard so it can be burned out before the heat of the day. The line can also be widened along these sections.

c. Advantages of Direct Attack

- Because there is a limited amount of fuel between the edge of the fire and the fireline, the fire has little chance of gaining momentum and spotting across the fireguard.
- Firelines can be kept to a minimum width, usually one blade.
- Burning-out may not be required.
- This method takes advantage of the fire perimeter in which the fire has subsided or gone out on its own.
- There is less timber burned.

d. Disadvantages of Direct Attack

- Because of the irregular shape of a fire, a longer fireguard may be required.
- A concentrated effort is required to ensure live embers are not pushed outside the guard.
- This method cannot be used on hot-burning fires.
- Direct attack may require airtankers or helitanker support to

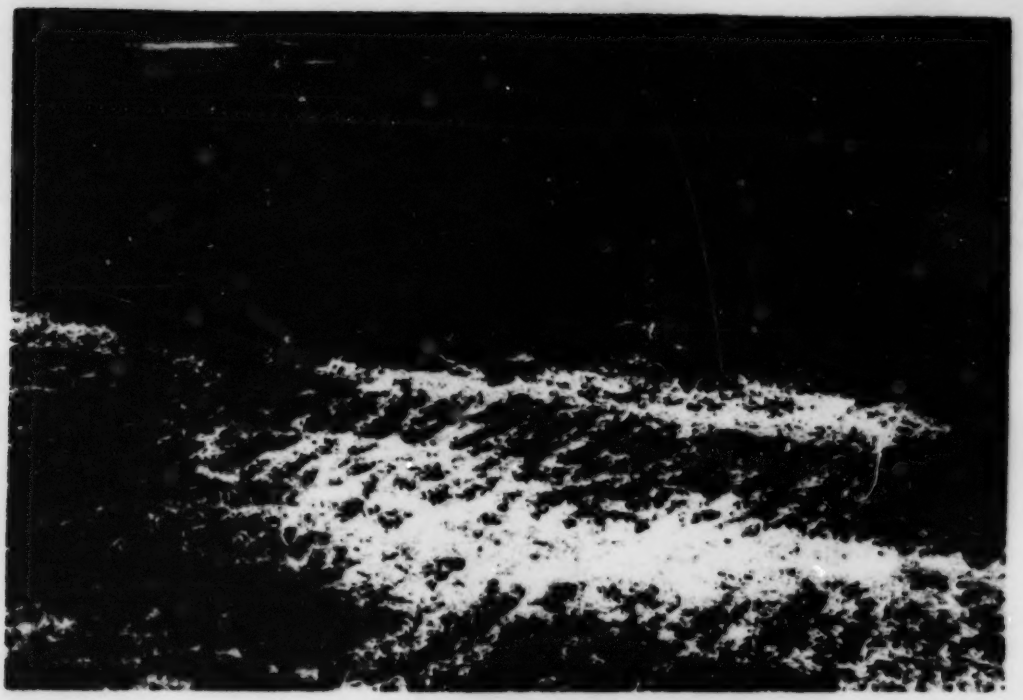


Photo 4. Direct attack methods should be used on slower-moving fires where portions of the perimeter may go out on their own.

Photo 5. Frequently, airtankers can adequately cool fires of this intensity, permitting bulldozers to construct an effective fireguard.

reduce the safety risk.

- The efficiency of both men and equipment can be affected negatively by the intense smoke and heat.

5.2.2 Parallel Attack Method

This method is used usually when a fire is considered to be too hot for direct attack. Therefore, the fireguard is constructed a safe distance from, and parallel to, the edge of the fire. The fireguard is not restricted by the irregularities of the fire perimeter, and can cut across bays and fingers to result in a straighter, shorter line. The distance between the fire's edge and the fireguard may vary from approximately 10 m to 100 m or more. The line scout has more freedom to select routes that will present the fewest problems for constructing a fireline, holding the fire and performing burn-out operations.

The parallel method of attack is used commonly in conjunction with the direct attack method. Bulldozers work along the edge of the fire (direct attack) when possible, and retreat when conditions become too hot or smoky (parallel attack). The parallel technique is used usually on moderately intense fires, or on the rear and flanks of high-intensity fires. Because this method leaves more flammable material between the fire's edge and the fireguard than does the direct method, the fireguard may have to be wider, but seldom more than two blades in width. The width of the fireguard and its distance from the fire's edge will depend on the behavior anticipated for the fire adjacent to the fireguard.

Organization for the parallel attack is somewhat more elaborate than for the direct attack. Burning-out must be conducted in conjunction with constructing the fireguard, or as soon as possible in the morning if the line is constructed at night. If burning-out is not used, the fireguard is of limited value, being no better than an access trail. Burning-out increases the effectiveness of the fireline, with a much

wider burned-over strip.

With few exceptions, debris should be pushed outside the fireline. Fireguards are not normally constructed above and ahead of a fire on a steep slope. When this occurs, however, debris may have to be pushed to the fire side of the fireguard. The debris can be covered with mineral soil to reduce fire intensity along the line.

a. Advantages of Parallel Attack

- This method can be used on hotter fires than can the direct attack.
- The length of the fireguard is less than with direct attack. The guard can also be constructed across bays and fingers, rather than following the irregular fire perimeter.
- Men and equipment are not subjected to heat and smoke to the same degree as in the direct attack.
- This method allows for greater flexibility when dealing with minor environmental concerns.
- The line scouts can take advantage of natural breaks and less flammable types of fuel.
- Usually, less timber is sacrificed than when using the indirect attack method.

b. Disadvantages of Parallel Attack

- Organization of this method is complicated by the fact that burning-out becomes an integral part of this attack.
- Burn-out fires can become uncontrolled.
- The fire will be larger than those on which direct attack methods are used.
- This method does not take advantage of sections that have burned out on their own.
- Safety concerns become more relevant since blow-ups can occur quickly, resulting in hazardous working conditions for both men and equipment. Aerial surveillance, as well as excellent

communication, is essential during critical burning periods.[1]

5.2.3 Indirect Attack Method

Indirect attack is used only where overhead fire personnel have decided that the chances of other methods succeeding are not great enough to warrant their use, or when the safety of men and equipment is at risk. Indirect attack is normally used during periods of high fire hazard and must include burning out (Photo 6).

This method is used frequently for frontal action, or potential frontal action, on very hot fires. It involves constructing a fireguard well back from the edge of the fire (usually more than 100 m), and taking advantage of any existing natural barriers and less flammable fuel (Photo 7). As with most other methods, debris is normally pushed outside the fireline.

The indirect attack method is complicated by the fact that a comprehensive burn-out program must follow line construction. The material should not be ignited until the fireguard has been completed, conditions are favorable, and the resources are in place. A common ignition pattern for burning-out involves burning consecutive strips of land starting at the fireguard, which may be natural or man-made. The first line can sometimes be ignited by ground crews, while subsequent ignition is normally carried out by using aerial ignition.

The actual construction of the fireguard differs little from the parallel method. However, the backfire may be hotter, making it necessary for the guard to be slightly wider. In addition, greater care must be taken to break up fuel accumulations and create escape routes.

a. Advantages of Indirect Attack

- This method can be used successfully on more intense fires than can other methods.

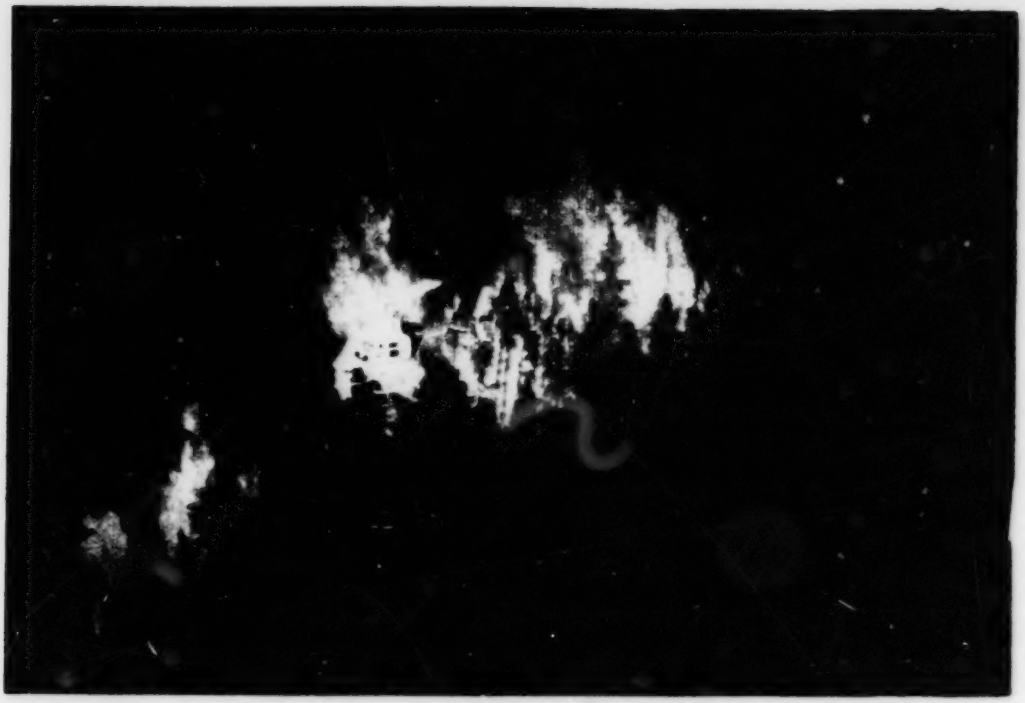


Photo 6. Indirect attack is the only alternative on more intense fires.

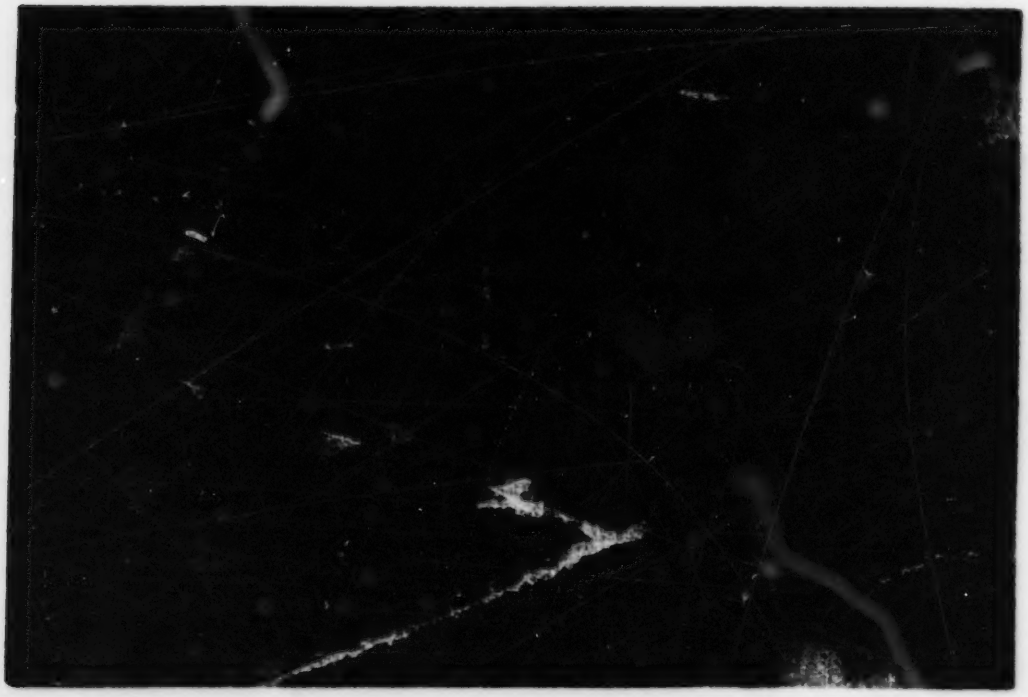


Photo 7. On fast-moving fires, indirect attack techniques may be considered, using existing barriers.

- Men and equipment are not affected by heat and smoke from the main fire while they are constructing the fireguard.
- Because of the distance between the fire and the fireguard, men and equipment can work more safely around hot-burning fires than with other methods.
- This method allows more flexibility when dealing with environmental aspects.
- The length of the man-made fireguard can be minimized by using natural barriers.
- Burning-out can take advantage of favorable topography and less flammable types of fuel.
- Because of the distance between the fireguard and the edge of the fire, the timing of burning-out is more flexible.

b. Disadvantages of Indirect Attack

- More timber is sacrificed than with other methods.
- The risk of a fire escaping is high because of the volume of fuel to be burned out.
- This method can result in more mopping-up if the main fire subsides.
- All lines must be constructed before backfires are ignited.
- Escape routes are more critical when indirect attack is used.
- Aerial ignition may be the only viable technique for igniting backfires.

5.3 Mop-Up

Regardless of the technique used, or the combination of techniques for controlling the spread of the fire, mop-up should progress in conjunction with line construction to ensure the fire has no chance of escaping. Most of this work is carried out by ground crews. On larger fires this involves extinguishing all burning material on a wide strip to widen the fireguard. On smaller fires, all burning material is extinguished.

Bulldozers and skidders can speed up mop-up and increase its effectiveness by breaking up piles of burning material, rolling logs, uprooting burning stumps and pushing over burning snags, thus allowing ground crews to extinguish any smoldering material. In some cases, this material is buried with mineral soil.

Skidders perform functions similar to bulldozers during mop-up, but can travel much faster, are more versatile and can be mounted with a water tank. In areas with limited water supplies, one skidder may do the work of 10 or more men.

6.0 FUNDAMENTAL STANDARDS FOR CONSTRUCTING BULLDOZER FIREGUARDS

As with other suppression techniques, certain criteria must be met to ensure the maximum success of the operation while continuing to maintain high standards. Bulldozers are not a solution by themselves; their use must be supervised properly and integrated with other methods and techniques to be effective. Where applicable, burning-out and patrolling should be part of any bulldozer fireguard construction.

6.1 Width of Fireguard

The width of a fireguard should correlate to the fire behavior anticipated along that line, whether it is the actual fire or the result of burning-out. There is a tendency to substitute extra width for the proper integration of techniques in constructing a fireguard. A bulldozer fireguard that is one or two blades wide and reinforced by other means, is usually more effective than wider fireguards and requires less restoration work. Some common methods for reinforcing fireguards are as follows:

- men with hand-tools;
- pump crews;
- skidders with water tanks or tracked vehicles accompanied by

pump crews;

- helitankers or airtankers;
- burn-out crews; and
- treating unburned fuels inside the fireguard (walking down trees adjacent to the fireguard).

The width of bulldozer fireguards can be minimized by incorporating one or more of the techniques listed above. This approach has proven to be more effective for subduing the spread of fire, and creates less environmental damage than do wide fireguards that have no reinforcement. The presence of an excessively wide fireguard generally indicates a lack of responsible supervision, the unavailability of required support, a lack of knowledge regarding the use of bulldozers, or the failure of fire overhead staff to use proper suppression techniques (Photo 8).

The general rule of thumb is to construct the narrowest fireguard possible using the tools, tactics and techniques available to stop the spread of the fire. Some of the factors that will dictate the width of the fireguard include the following:

(1) Short, sparse stands do not generally require as wide a guard as do taller, denser stands of the same species.

(2) Fuel arrangement will dictate the width of the guard:
   - black spruce stands usually have a combination of moss and dead branches ranging from near the ground to the living crown; this material is ideal for promoting torching or crown fires.
   - there is a concentration of heavy fuels that generate intense heat.

(3) Tree species and age will affect fire behavior.
   - immature pine and white spruce are relatively fire resistant;
   - black spruce stands are very volatile and will promote rapid spread of the fire, even under moderate fire hazard

conditions;

- aspen stands can often be used as a fuel break after green-up. Crown fires are very rare, but they can occur when leaves are just emerging.

(4) Current or forecasted weather factors.

- increasing temperatures and decreasing relative humidity will increase the intensity of the fire.
- changes in wind direction and an increase in wind speed may affect the desired width of the fireguard.

(5) Topography

- fires burn faster and with greater intensity when they are moving uphill than do those burning downhill.

(6) Availability of additional forces to reinforce the fireguard, and the time required to have them in place.

- can the fireguard be reinforced before the fire arrives, or should the bulldozers construct a wider fireguard?

(7) Environmental impact

- what technique or combination of techniques would subdue the spread of the fire with the least environmental damage?

6.2 Depth of Fireguard

The purpose of a fireguard is to provide a fuel break, thus stopping any further spread of the fire. In the case of man-made fireguards, all combustible materials must be removed, which usually means a portion of the topsoil must be removed. Some important factors to consider include the following:

(1) A properly constructed fireguard virtually eliminates the possibility of a fire burning across the line.

(2) Caution must be exercised to ensure all roots have been severed, since they can create a potential fire route, especially in black spruce stands during extended periods of drought.

(3) In some cases such as with muskeg, it may be impractical and

unnecessary to construct the fireguard down to mineral soil. Under these conditions, all flammable material must be removed down to an unburnable fuel layer, or an unburnable fuel must be created in one of the following ways:

- A guard constructed down to the frost layer is effective until the frost thaws and the organic layer dries out.
- In areas of deep duff, a man-made, non-combustible layer can be created by allowing water to seep into the fireguard, or by wetting down the organic matter using power pumps.
- In some cases, an adequate firebreak can be made by a bulldozer pushing just enough material to cause it to make ruts that will then fill with water.

6.3 Avoidance of Adding Fuel to the Fire

When constructing fireguards, either by hand or by bulldozer, it is generally accepted that **all unburned flammable material should be pushed away from the fire.** This is extremely important when constructing a bulldozer fireguard because of the volume of material being removed, which will have a direct bearing on the effectiveness of the fireguard and the effort required to subdue the spread of the fire (Photo 9). Some considerations include the following:

- Removing flammable fuel reduces the potential for the fire to gain sufficient momentum and intensity to spot across the fireguard, or to cause fires on the opposite side of the line to ignite through heat radiation.
- This will reduce the quantity of potentially flammable fuel, thus reducing manpower, equipment and time requirements to allow a successful burn-out to occur with a lower risk to men and equipment.
- Moving flammable fuel away from the fire lowers the possibility of the fire getting into this mixture of dirt, wood, duff and other debris, and reduces the time and effort required to

Photo 8. Excessively wide fireguards are generally less effective than reinforced, narrower fireguards.

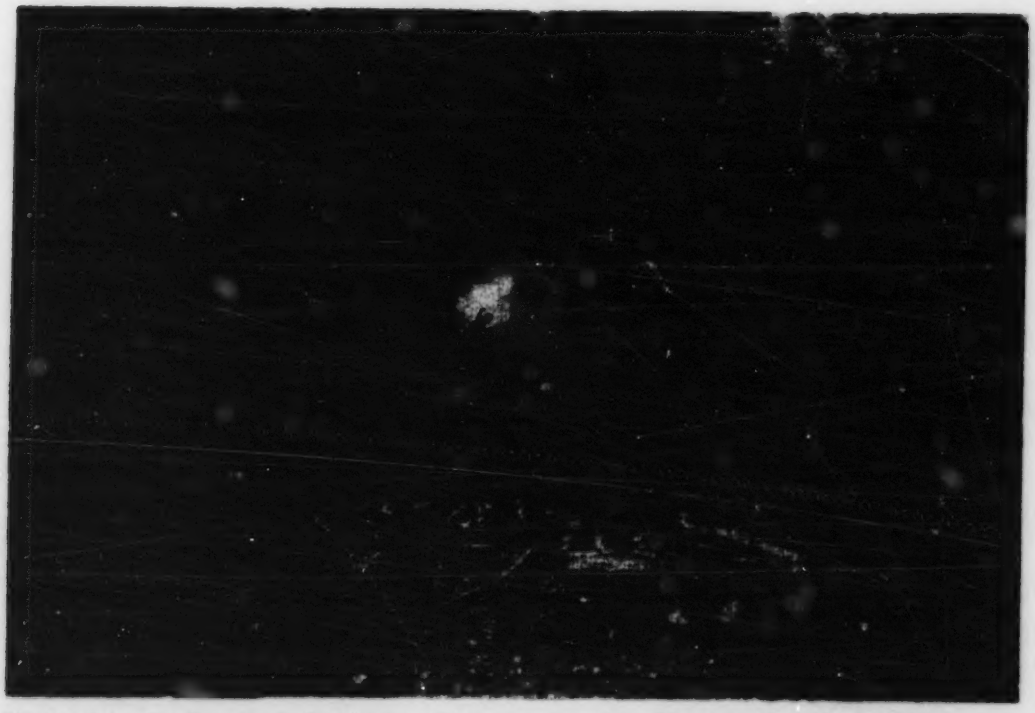


Photo 9. Fuel accumulations adjacent to the fireguards should be broken up and spread out prior to burning-out.

extinguish the fire. If the fire does enter this mixture, it can smolder for days or weeks until it erupts with disastrous consequences.

- By keeping the fire out of the above-described mixture, reclamation work can proceed without crews having to extinguish latent fires.

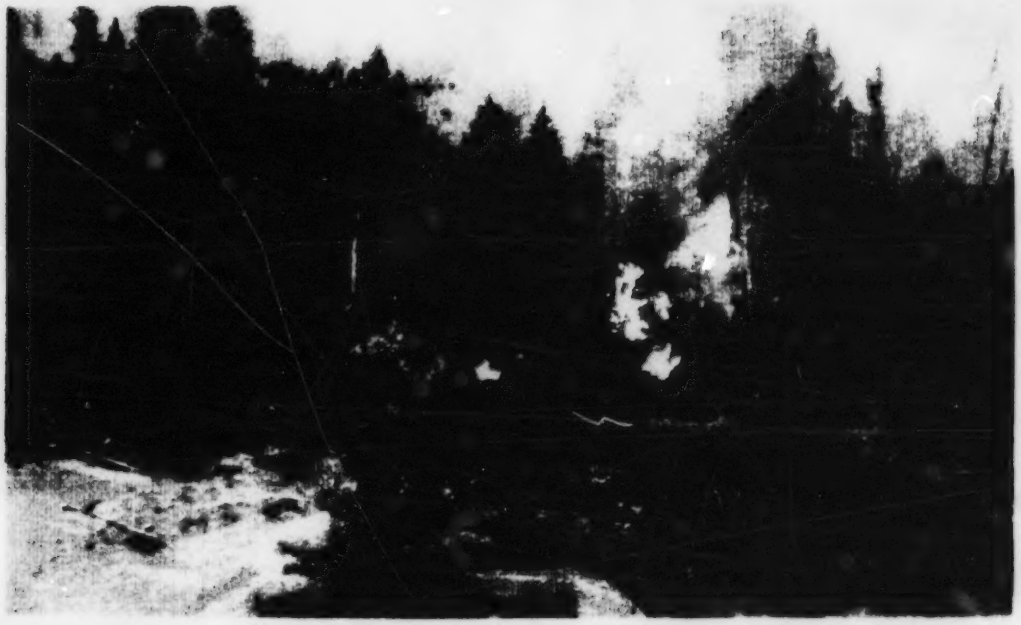
Under certain circumstances, it is acceptable to push debris to the fire side of the fireguard. These include the following:

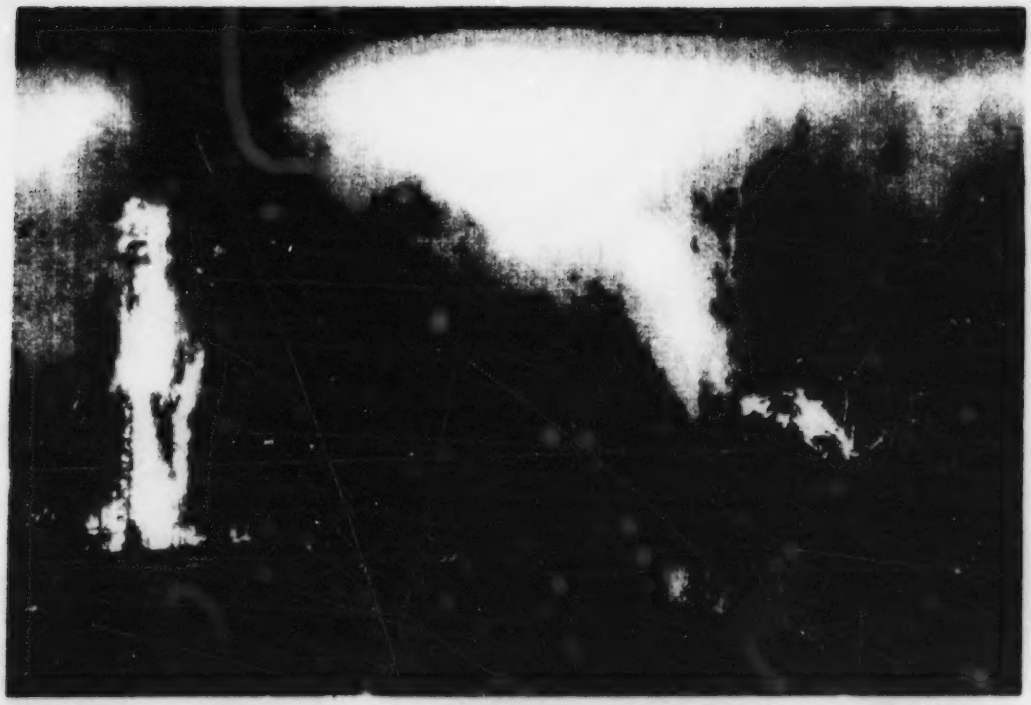
- The degree of side slope can make it impractical to push debris uphill. In such cases, the debris may be pushed towards the fire, but the amount should be minimal. This can be accomplished by working on the edge of the fire, if possible.
- Any material that is burning, or has burned previously, should be pushed into the fire as a precautionary measure.
- Fires may burn for several metres along black spruce roots. If the parallel method is used, the fire may never reach the fireguard; if the direct method is used, burning roots may be pushed outside the fireguard. If these fires occur in the fall, it may be necessary to push debris toward the fire side of the line, in hopes of containing the fire until snow falls and the piles can be broken up and spread over the ground.

6.4 Use of Natural Breaks and Barriers

Overhead fire personnel must continually analyze their existing strategies to ensure that the fastest, most effective building programs for fireguards, which create the least amount of environmental damage, are in place. Therefore, the cat boss must be informed of any natural firebreak that can be used (Photos 10a, 10b).

The effectiveness of natural barriers will depend on the type and size of barrier and the intensity of the fire. Narrow creeks or other wet areas may be used to help stop low-intensity fires. However, even





Photos 10a and 10b. Burning-out can be conducted from man-made fireguards or natural barriers (10a), but should be supported by a helitanker, airtanker or fire crews to suppress spot fires (10b).

rivers or lakes are sometimes ineffective against intense fires; such fires may spot several kilometres from the main fire. Poplar stands are often effective in stopping low and moderately intense fires for the period following leaf emergence and before fuels "cure" in the fall (Photo 11). Generally, lakes, rivers, creeks and roads are effective at subduing wildfire, depending on the size of the barrier and the intensity of the fire.

Pipelines, power lines and seismic rights-of-way, as well as cutlines and swamps, can often be used for part of the fireguard. The duff layer in these areas may have to be removed, or this barrier can sometimes be reinforced through the use of power pumps, hand-tool crews or aircraft. By recognizing and using such barriers, suppression efforts can be accelerated, often with minimal environmental impact, allowing the cat boss to concentrate on priority areas or additional line construction.

6.5 Constructing Bulldozer Fireguards at Night

6.5.1 Advantages/Disadvantages of Operating Two Shifts

Often, the most effective time for fighting fires is lost because overhead fire personnel are reluctant to either have a crew work during the night or work during a period when safety measures cannot be put in place. If two shifts are not part of the strategy, suppression may be jeopardized because of the following reasons:

- The same crew cannot and should not be expected to work the entire span of daylight hours during the spring/summer months.
- Suppression efforts that could otherwise occur during the first few hours of daylight and the last couple hours before dark are often lost because of the time needed to organize and transport the crews to the site.

Since all reasonable efforts must be made to bring a wildfire under control, the advantages of operating two shifts must be considered.

The following points further illustrate this view:

- Often, the only effective bulldozer fireguard is created during the night or early morning.
- Night or early morning may be the only times that fireguards can be constructed safely along the flanks and at the head of a fire, since fires usually burn less intensely during these times.
- Although night construction may be slower, the bulldozers should be in full production by daybreak.
- The frequency of accidents increases significantly when shifts are longer than 10 hours. When only one shift is operating, there is a greater tendency to have the shift exceed the 10-hour limit.
- Smoke and heat are usually less intense during the night and early morning. This allows bulldozers to work closer to the edge of the fire.
- Fireguards constructed during the night should be "burned out" or reinforced before the peak burning period occurs in late afternoon (Photos 12 and 13).
- Worker morale is usually higher when working shorter shifts.

However, constructing fireguards on a 24-hour basis can have some negative aspects. Some examples include the following:

- Organization and safety programs must be more elaborate.
- Fireguard construction is generally slower at night.
- Locating line is more demanding and difficult at night.
- Bulldozer operators can become disoriented at night; operators showing this tendency should not work a night shift.
- Construction of bulldozer fireguards at night can be more dangerous, even with reasonable safety measures in place. As an example of this, sometimes conditions are such that the behavior of the fire remains or becomes very erratic. In addition, walking down trees is dangerous (especially if snags are present) and should be done during daylight, if possible.

Photo 11. Fire suppression personnel are urged to take advantage of less flammable types of fuel.

Photo 12. Burning-out should be completed before the heat of the day on a fireguard constructed during the night.

6.5.2 Guidelines for Constructing Firequards at Night

Bulldozer fireguard construction at night should be carried out only according to agency policy and prescribed safety standards. Suggestions have been made by forestry personnel, bulldozer operators and contractors for increasing the safety and effectiveness of night operations. Since each fire is unique, the following lists only the major concerns.

- Bulldozers should never be operated at night without proper supervision and established safety procedures.
- The cat boss should be in radio contact with personnel in camp, to increase safety should an accident occur.
- The sector boss should know of the available helicopter pilots who are licensed for night flights, should a rescue mission become necessary.
- Both the line scout and lead operator should be equipped with a communications kit and good sealed-beam or halogen flashlights.
- Before fireguard construction occurs, flashlight signals must be established with the lead operator.
- In the evening, the line scout may want to be dropped off at the point to which he believes the bulldozer operators will be able to construct the fireguard during the nightshift. From here he can locate and mark line back to the bulldozers.
- Key areas should be marked and crews transported to creek and pipeline crossings to provide assistance.
- Walking down trees is the most dangerous aspect of constructing fireguards at night; therefore, line should be located and timber walked down before nightfall, if possible.
- Shift changes should occur two or three hours before darkness to allow the bulldozer team time to become familiar with the terrain and fire.
- If the bulldozer team is dropped off by helicopter, flying over the work area will provide them with a better idea of what to expect during their shift. Areas of concern should be noted

and possibly marked at this time.

- The line scout cannot properly locate line while riding on the lead bulldozer. Bulldozer operators should not be expected to be responsible for the safety of a passenger, since this exerts unnecessary pressure on the operator.
- Several helicopter landing pads should be constructed to enable evacuation to occur during the night.
- If fireguards are to be constructed during the night, this should be done only in accordance with existing safety programs (see Section 9.0, Bulldozer Safety Considerations).

6.6 Reinforcing Fireguards Using Bulldozers

If wildfire control is to be successful, suppression personnel must be able to adapt to the unpredictable changes of the fire. Strategies may have to be altered based on the concentration of unburned fuel lying between the fireguard and the fire, the safety considerations, and changes in fire behavior or variations in the weather (Figure 5). Fireguards constructed during the night, or those constructed in haste, may have to be reinforced using one or more of the following methods:

- Fireguards may have to be deepened if combustible material still remains.
- Fireguards may have to be widened to contain the actual fire or accommodate burning-out operations (Photo 14).
- Trees that have either fallen across the line or are likely to fall may have to be removed.
- If the potential for crowning exists, trees may have to be walked down inside the fireguard. Black spruce stands, and those having a balsam fir understory, are very susceptible to crowning because of the "laddering"-type fuel arrangement. Removing aerial fuels confines the fire to the ground. This technique is very effective if the ground is moist, since the branches will absorb some of this moisture and become more fire

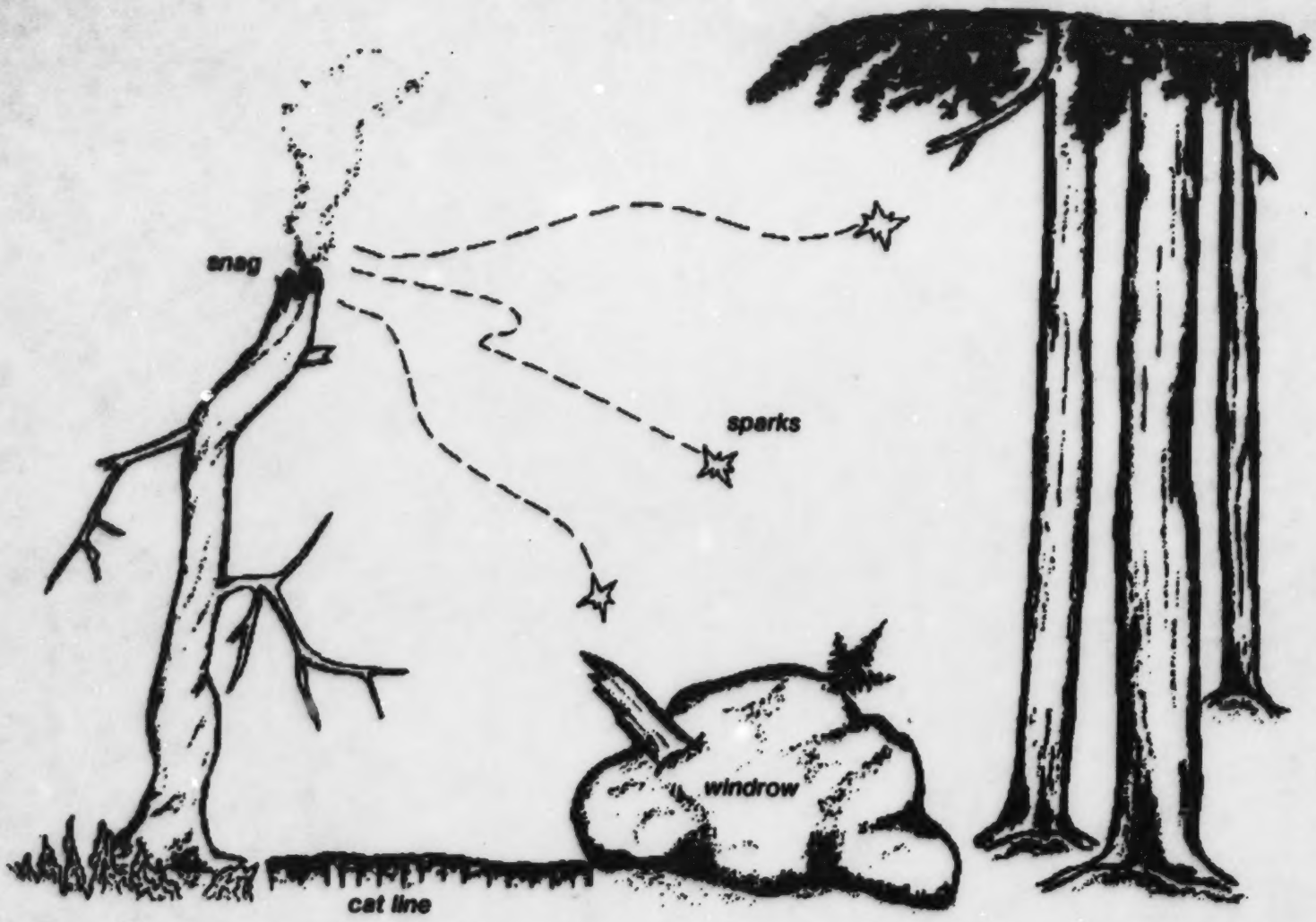


Figure 5. Chimney fire.

Photo 13. The common result of a fireguard not having been properly reinforced or where burning-out was neglected.

Photo 14. Bulldozers reinforcing a previously constructed fireguard before burning-out occurs.

resistant.

6.7 Bulldozers as an Integrated Tool

No single suppression technique is totally effective over a wide range of conditions. To achieve environmental and fire suppression objectives while still meeting safety requirements, bulldozer units may have to alter their tactics based on the following information.

6.7.1 Fire Crews

Fire crews can increase the effectiveness and speed of a bulldozer operation in several ways:

- Clean-up, burn-out and patrol crews should be an integral part of any bulldozer unit.
- Use of fire crews should be considered when steep banks along coulees, creeks or rivers are encountered. If hand-tool, power-pump or hot-spotting crews can be used to stop the fire in such areas, the environmental damage and restoration costs will be minimal compared to bulldozer fireguard construction.
- Fire crews should work ahead of the bulldozer unit when crossings are required over creeks or pipelines, thus ensuring completion before the bulldozers arrive.
- Use of fire crews should be considered when soil and moisture conditions are encountered that may have an adverse effect on bulldozer fireguard construction.
- Fire crews can be used to strengthen the fireguard along key problem areas.

Some manuals have suggested that chainsaw crews should work ahead of the bulldozer units to buck windfalls and perform other related duties in preparation for the units. However, the general consensus among fire personnel is that if a bulldozer is not capable of breaking the types of trees common to the boreal forest, it should not be used in

fire control.

6.7.2 Helitankers

Helitankers are helicopters equipped with helitanks (specially designed tanks fitted to a helicopter and used for transporting and dropping fire suppressants or retardants). They are extremely useful for cooling hot spots lying ahead of the bulldozers, thus allowing the machines to work closer to the fire's edge than would otherwise be possible. In addition, behind the bulldozer unit helitankers act as a valuable support tool for cooling flare-ups and holding any spot fires that are threatening to cross the line.

Because helitankers hover when making a drop, they can work close to the bulldozers or crews without creating a safety hazard. When working in close proximity to men and equipment, helicopter pilots can often observe any changes in fire behavior and inform ground personnel.

6.7.3 Aerial Ignition Device

Helicopters that are equipped with aerial ignition devices enable suppression crews to backfire and burn-out areas that are considered unsafe for ground ignition. Delayed aerial ignition devices and helitorches are included in this category.

6.7.4 Airtankers

Airtankers are fixed-wing aircraft fitted with tanks and equipment for dropping suppressants or retardants on fires. They are also called fire bombers and water bombers. Airtankers are used frequently to cool hot spots or flare-ups on the edge of the fire, thus enabling bulldozers to work closer to the fire perimeter (Photo 15). They cannot work as closely to men and equipment as do helicopters without creating a safety hazard; therefore, all safety measures must be followed.

6.7.5 Skidders

Although skidders are used occasionally to construct limited portions of fireguards, their main function is to provide support. Sometimes they are used for the initial attack on smaller fires burning in light fuel types. Skidders require much less time to reach the problem area than do bulldozers. In addition, skidders with water tanks mounted on them can significantly increase the effectiveness of direct attack and mop-up crews (Photo 16).

Skidders are particularly valuable for supplying water, and pushing or digging out smoldering material during mop-up. Water tanks can be mounted on skidders without affecting the machine's winching capabilities.

Care should be taken to ensure skidder tires do not catch fire, since they are extremely difficult to extinguish.

6.7.6 Water Trucks, Nodwells, Hildebrants

A wide range of equipment has been used successfully to support fire control or provide a means of transportation for men, equipment and water. Nodwells, usually moving by means of tracks, and Hildebrants, usually equipped with tires, are two types of machines that can be used to transport equipment and personnel. A lowboy may be attached to either to increase carrying capacity.

6.8 Construction of Helicopter Landing Pad (Helispot or Helipad)

Helicopters have become widely used in fire control because of their versatility and flexibility in being integrated into a range of suppression procedures. However, because of their higher costs ($600 to $2000 per hour plus fuel), an effort must be made to ensure they are used fully and wisely.

Often, helicopters can land in natural openings or on previously

Photo 15. An effective fireguard reinforced by an airtanker.

Photo 16. Tanked skidders have proven very beneficial for reinforcing existing fireguards and enhancing mop-up activities.

constructed openings such as roads or seismic lines. If such areas are not available, the cat boss must ensure that an adequate number of well-constructed helipads are available. Before construction occurs, the following points should be considered:

- Potential areas should be located and helipads constructed during the initial fireguard construction rather than requiring a bulldozer to backtrack to do the work at a later time.
- Normally, helipads are located at intervals of one to two kilometres.
- Natural clearings or areas with short vegetation cover should be used when possible. Helipads constructed in tall timber take longer to construct, must be larger than pads built in more open areas and result in wasted timber.
- Dry areas are preferred to wet areas for construction.
- The topography should be considered before construction to ensure the helipad is located on the site that will best facilitate landing and lift-off.

Certain specifications must be met to ensure the safety of helicopters when using helipads (Figure 6). These include the following:

- The size of the helipad should be relative to the size of the helicopters that will be using it. If the timber is less than 10 m in height, the helipad should be a minimum of 23 m^2. If the timber is greater than 10 m in height, the minimum acceptable diameter of the helipad is 2.5 times the height of the trees.
- When piling debris that has been removed from the helipad during construction, a minimum width of one bulldozer blade must be left between the piles of debris and standing timber. This practice will simplify reclamation work, since all debris must be scattered back over the clearing.
- Debris that might become entangled in the helicopter skids or rotor blades should be removed from the site.
- On uneven terrain, the helipad should be located on as high an

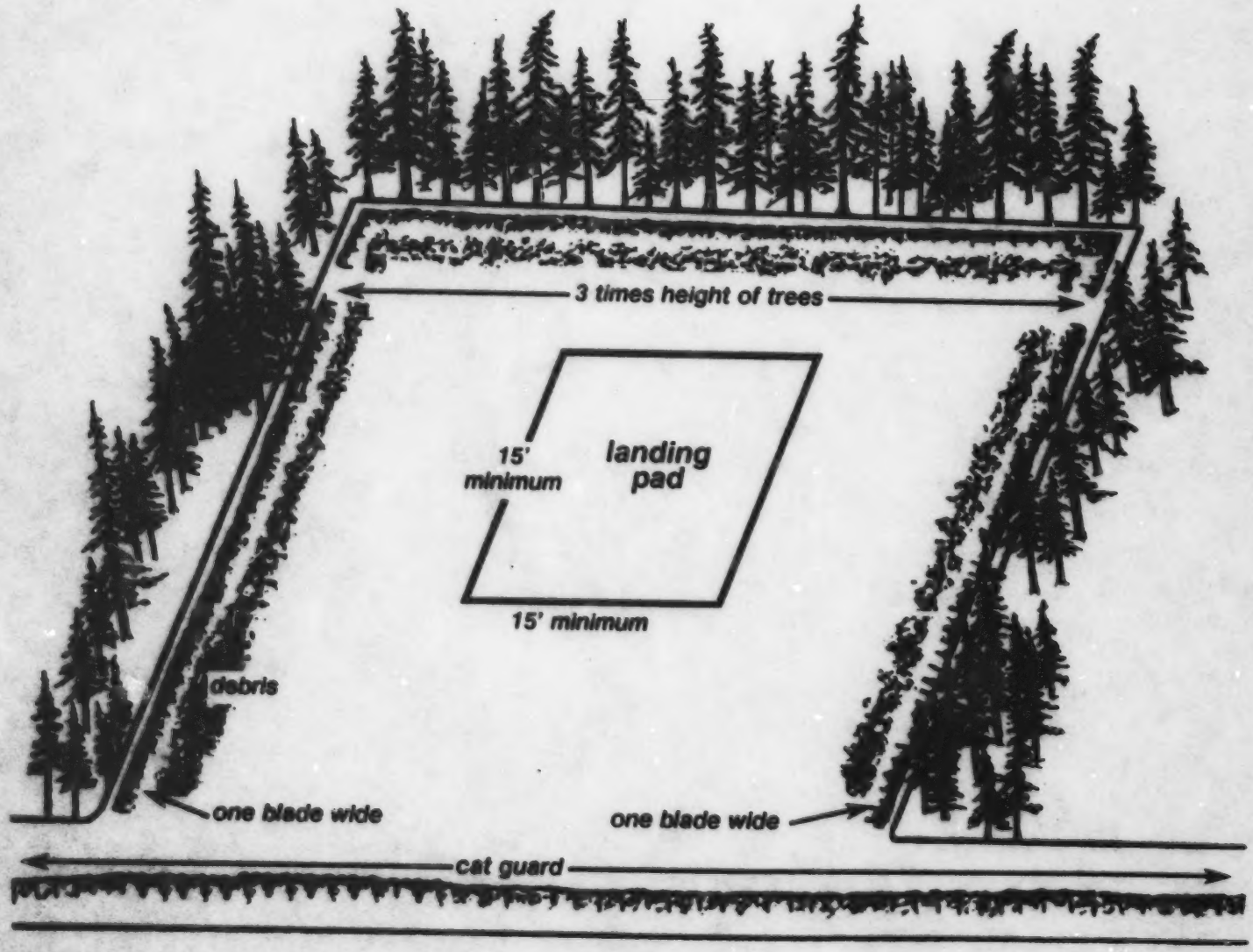


Figure 6. Helispot construction.

elevation as possible, but the slope should not exceed 2%. The actual helipad landing spot should be approximately 10 m^2.

7.0 MAXIMIZING BULLDOZER PRODUCTIVITY

7.1 Productive Time Versus Non-productive Time

During the bulldozer productivity study undertaken by NOFC, non-productive time varied from fire to fire, depending on fire behavior, duration of fire and bulldozer unit organization. Productive time averaged 60% of the total time for all campaign fires. On smaller fires and initial attack situations, productive time was much higher, although an accurate percentage could not be determined because of insufficient data. The reasons for non-productive time included the following:

- Bulldozers waiting for other machines to arrive before the unit could be dispatched.
- Halting fireguard construction because of unsafe working conditions.
- Bulldozer(s) stuck.
- Routine servicing of machines.
- Mechanical malfunctions.
- Waiting for line to be located.
- Any other work stoppage in fireguard or helipad construction, whether avoidable or not.

Most non-productive time was considered to be unavoidable, since machine maintenance and servicing, line location, stuck bulldozers and mechanical malfunctions are inevitable. Safety of people must take precedence over suppression objectives, regardless of the circumstances. However, non-productive time can be reduced by complying with some basic standards, as outlined below:

- Only bulldozers in good mechanical condition, owned and operated by reputable people or firms, should be hired.

- The bulldozer that is best for the job should be hired. Low ground pressure bulldozers have proven very effective in most boreal forest types providing they have met the horsepower requirements. If steep slopes may be encountered, and where moisture and soil conditions permit, standard gauge tracks will provide better traction.
- The number of bulldozers per unit should not exceed three, unless circumstances warrant additional machines. When bulldozer units are too large, operators have difficulty in distributing the workload.
- A qualified cat boss should be assigned to supervise the activities of each bulldozer unit. Line scouts, swampers, and clean-up and burn-out crews are an integral part of most bulldozer fireguard operations. When one aspect of the unit is not supervised properly, the entire operation may be jeopardized.
- When working during the nightshift, line should be walked down before dark. If this is not possible, however, the line should be well marked so bulldozer operators do not become lost.
- Instructions must be relayed through the proper channels. Bulldozer operators can become confused if conflicting instructions come to them from different sources.
- Other techniques should be integrated where necessary. Time should not be wasted on short sections of line that could be contained more efficiently by using other methods.
- Hiring personnel from the private sector to fill positions such as cat boss and line scout has proven beneficial. However, it is recommended that these personnel not be assigned to bulldozer units with which they are employed under normal conditions.
- When transporting bulldozers to a fire and getting bulldozer units mobilized, there may be a period of several hours between the arrival of the first and last bulldozers within a unit. Normally, bulldozers should begin constructing fireguards as

soon as possible without waiting for the entire unit to arrive. Late arrivals will then catch up.

- Operators who refuse to follow directions and safety guidelines must be replaced.
- A concentrated effort must be made to maintain employee morale at an acceptable level if high productivity levels are to occur.

When bulldozer units become too large or are not properly supervised, the following may occur: lines are made unnecessarily wide, too much mineral soil has been removed, or the fireguard has been constructed around bays and fire fingers. By following the above recommendations, the percentage of time that is actually productive could likely be increased to a minimum of 70% and 90% for campaign fires and initial attack situations, respectively.

7.2 Employee Morale

Maintaining good employee morale may be the single most important factor in sustaining acceptable levels of production, especially on a campaign fire. Concerns related to morale include the following:

- Bulldozer operators hired in late afternoon or evening should not be expected to work during their first night, unless the employee willingly agrees. Should this occur, it may be good practice to replace the dayshift operator with the nightshift operator two to three hours before dark to allow the night worker adequate time to familiarize himself with fire conditions. Not only is this important to general morale, but it is a good, general safety practice as well.
- Sometimes, bulldozer operators do not know when a shift is to end, which creates some uncertainty for the worker. On the other hand, sometimes the end of the shift is known, but the shift is extended without consulting the operators. Bulldozer operators should be included in any decision making, if

possible.

- Two 10- or 12-hour shifts should be considered for extra period fires, rather than operating one longer shift.
- When running a single shift, bulldozer operators are often the first to leave camp in the morning and the last to return at night. Supper should have been prepared and waiting for their arrival at camp.
- If overhiring occurs, owners of bulldozers that have little or no operating time should be compensated. This amount must cover the owner's expenses.
- Normally, bulldozer operators should not work longer periods than they feel comfortable with. Otherwise, efficiency decreases and accident frequency increases (usually when shifts exceed 10 hours).
- Bulldozer operators should be consulted when a nightshift is being scheduled. Some operators prefer working at night, while others become disoriented or are uncomfortable working in the dark.

8.0 ENVIRONMENTAL IMPACT OF BULLDOZER USE AND FIREGUARD RECLAMATION

8.1 Reclamation Considerations Before Fireguard Construction Occurs

Although the boreal forest is generally not as susceptible to irreparable environmental damage as are other forest regions, bulldozers should be used only in areas that can be reclaimed to near their natural state at a reasonable cost. Overuse of bulldozers will result in restrictions being placed on using bulldozers as an alternate suppression method.

Some of the old techniques, such as making fireguards as wide as possible, are no longer valid because of their negative impact on the environment. In recent years, fire overhead teams have had to become more versatile and resourceful in integrating techniques that agree

with modern ideology.

Constructing fireguards using bulldozers has generally been very effective in containing and controlling fires. However, massive reclamation work may be necessary if potential environmental impact is not considered in the initial planning. When attempting to bring a fire under control, the decisions regarding line location and the type of line to be constructed may be based primarily on fire suppression effectiveness rather than on potential erosion or reclamation problems.

The potential for erosion and sedimentation to result from bulldozer fireguard construction depends on the size of the soil particle and the surface condition/slope. Fine-grained soils (e.g., clay, silt) are extremely unstable and very susceptible to erosion. Coarse-grained gravelly soils are much more stable and less prone to erosion. Therefore, specific efforts are necessary to control erosion, prevent stream siltation and promote revegetation.

At the onset of a fire, reclamation requirements must be considered with any decisions regarding fire suppression tactics. Such crucial decisions will not only be regarding the time required and the cost of suppression, but also affect the effort and expense involved in restoring the area.

Personnel must remember the final objectives of post-fire reclamation when they are locating line and monitoring bulldozer fireguard construction. Adaptability and strict coordination of suppression activities will assist achieving the following reclamation objectives:

- Blend bulldozer fireguards into the original landform.
- Restore the original drainage pattern.
- Restore or improve the original level of land productivity.
- Re-establish a self-sustaining vegetation cover that is consistent with that of the surrounding area. This is to

stabilize the disturbed soil and minimize erosion.

By adhering to some basic ground rules and avoiding situations that would be detrimental to restoring bulldozer fireguards, the above objectives can be achieved with less effort. Basic considerations include the following:

a. Bulldozer fireguards should not be constructed straight up or down steep slopes. If soils are not susceptible to erosion, the fireguard may be angled up or downslope. Alternative suppression techniques may have to be put in place for more sensitive areas.

b. Heavy vehicle traffic results frequently in depressions that can cause minor gullies prone to erosion. Bulldozer operators should be advised of this potential for damage. Alternate routes may have to be established if other measures are not effective.

c. When possible, bulldozer fireguards should not be located on or near unstable areas, springs or seepages.

d. Stream crossings are best located:
   - at right angles to the stream;
   - at a narrow point along the watercourse;
   - at locations where channels are well defined, unobstructed and straight; and
   - at stable approaches.

e. If alternative suppression methods can be used, avoid constructing fireguards within:
   - 100 m of the high-water mark of any permanent watercourse;
   - 30 m of any intermittent watercourse; or
   - draws that periodically hold water.

f. Log fills should be used in place of dirt fills (Figure 7), but only if the following guidelines are observed:

- Crossing intermittent and temporary streams when fish passage is not necessary or when the stream channel is dry.
- The flow of water is not unduly obstructed and any backflooding is restricted to the stream channel.
- The logs can be bundled together to allow for easy placement and removal.
- De-limbed and lopped logs that are not attached to stumps should not extend beyond either side of the utilized surface by more than 1.5 m.
- If soil is placed on top of the log fill to facilitate vehicle movement, it should be separated from the logs by means of a synthetic mat or 0.4 m of conifer boughs.
- Log fills are to be removed after the stream has been crossed if unforeseen problems arise, e.g., flooding. If not already removed under the previous conditions, they must be removed before bulldozers leave the immediate area.

g. Fords offer acceptable crossing points, providing the following guidelines are observed:

- The streambank has a firm rock or coarse gravel bottom and stable approaches that can stand up to bulldozer travel.
- The fisheries resource or downstream water users are not critical factors.
- Improvements to the crossing should be limited to removal of large boulders, or debris from the stream within the right-of-way, that would interfere with vehicle passage.
- Access to the ford is not from the outside of any bend in the watercourse.
- The number of crossings are kept to a minimum.

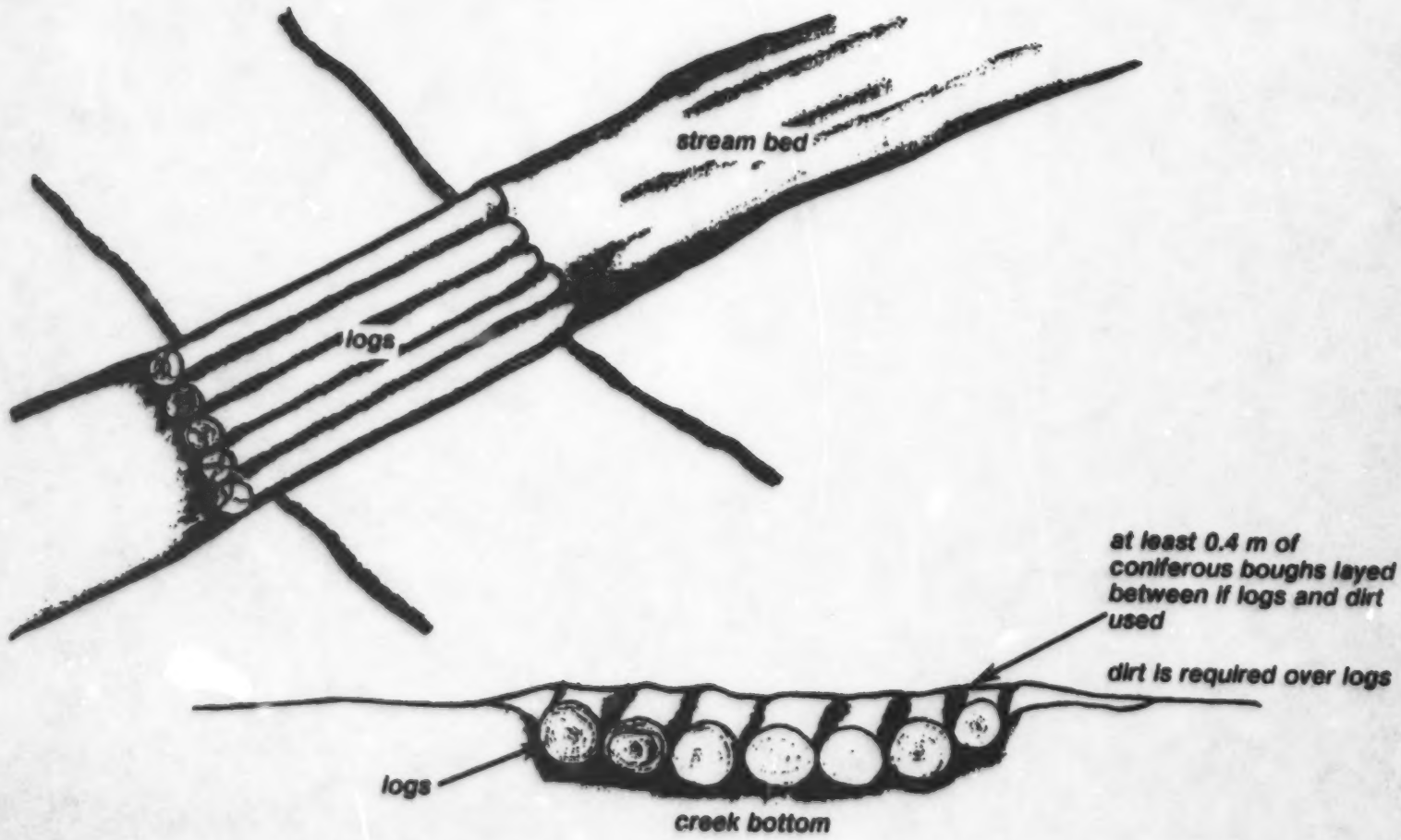

stream bed
logs
at least 0.4 m of coniferous boughs layed between if logs and dirt used
dirt is required over logs
logs
creek bottom

Figure 7. Log-fill creek crossing.

8.2 Bulldozer Fireguard Restoration

When the fire reaches the "being held" status, timber management and land use personnel should be notified so that restoration work and salvage operations can be coordinated. A restoration plan should be put in place and an adequate number of bulldozers should be retained to carry out the plan. Restoration of a fireguard should include the following:

- removal of any log fills used for crossing streams;
- cross-drains and diversion ditches installed where necessary to reduce erosion and stream sedimentation;
- restoration and stabilization of streambank;
- rollback of organic material and slash;
- compaction of debris;
- revegetation of all disturbed areas;
- recontouring, if necessary, where the fireguard was constructed across ridges, etc., especially in highly visible areas;
- repair of depressions resulting from repeated bulldozer traffic, whether or not they are on or off the fireguard; and
- measures taken to prevent unnecessary vehicle traffic in the future.

8.2.1 Cross-drains and Diversion Ditches

Cross-drains and diversion ditches are installed to intercept and divert surface run-off across fireguards rather than allowing water to flow along the fireline and create erosion ditches. These interception channels are constructed with hand-tools or the corner of a bulldozer blade.

8.2.2 Revegetation

Fireguards are revegetated to establish a dense root system that will retard soil movement. Grass mixtures should be selected on the basis of the particular soil type and the factors contributing to erosion for that site.

Indentations caused by bulldozer track cleats will assist in creating a microsite capable of promoting vegetation establishment.

8.2.3 Recontouring

Recontouring is required in highly sensitive areas or recreational areas where the construction of bulldozer fireguards has occurred across ridges, and does not coincide with the original contour of the landscape.

8.2.4 Spreading Debris

All unmerchantable debris removed previously from the fireguard during construction should be scattered over the fireguard and compacted using bulldozers. This will retard water movement through the area and reduce the impact of rain and wind.

9.0 BULLDOZER SAFETY CONSIDERATIONS

9.1 Importance of Safety

The safety of people, whether or not they are part of the fire control operation, must always take precedence. The sector boss and cat boss are directly responsible for the welfare of all personnel involved in operating the bulldozers. They must ensure that all personnel within their jurisdiction are operating within a safe work environment and are physically capable of performing their duties.

A review of U.S. Forest Service's records, between 1926 and 1976, shows that 145 men died from fire-related injuries on 41 fires. Some factors common to fatal fires include the following:

- relatively small fires or deceptively quiet sections of large fires;
- relatively light fuel, e.g., grass, herbs and light brush;
- unexpected change in wind direction or speed; and

- sudden flare-ups resulting from updrafts/downdrafts on slopes, air down-wash from helicopters, or impact from airtankers.

9.2 Cat Boss Responsibilities

Although many of the safety responsibilities are delegated to crew bosses and bulldozer operators, the supervision and enforcement should be carried out by the cat boss. The cat boss must be responsible for the following:

- Providing adequate communications equipment for his personnel. It is essential that a line scout, lead operator and sector boss be able to relay messages.
- Keeping current with any actual or anticipated changes in fire behavior.
- Planning two escape routes and ensuring that all personnel are aware of these routes should evacuation be necessary. Commonly used escape routes include the following:
  - deciduous stands;
  - burned-over area where smoke and heat are not too intense;
  - sparsely stocked wet areas.
- Making sure crew members and operators work reasonable shifts and do not become exhausted. Efficiency, safety and morale all suffer as a result of fatigue.
- Informing operators that personnel are working near the bulldozers. Lead operators should be warned to maintain a distance of at least two tree lengths behind the line scout.
- Ensuring that all machines are well maintained and free of debris that could start a fire, i.e., build-up of leaves or other similar vegetation in the belly pan or on the manifold that could be ignited.
- Ensuring that all bulldozers working on the fire are equipped with fire extinguishers and track shovels.
- Ensuring that pumps and hoses are available to operators who want to wash their machines.

- Discouraging the situation of a single bulldozer working alone.
- Being aware that bulldozers working on frost or rock can slide sideways unexpectedly.
- Making sure that no one aside from the operator is allowed on the bulldozer.
- Ensuring that all precautionary measures are taken when crossing pipelines. These include the following:
  - notifying the pertinent oil company of the need to cross their pipeline(s). Hopefully, pressure within the pipe can be reduced before the crossing occurs;
  - notifying the bulldozer operator of the pipeline;
  - determining the exact location of the ditch and whether the pipe is visible;
  - constructing a pad over the berm. A dirt fill of 1 m will be adequate for the machines to cross; and
  - making sure all machines cross at this single point.
- Ensuring that all crew members and bulldozer operators know the proper procedure to follow during airtanker drops (Figure 8).
- Informing operators of a planned nightshift, and making sure all extra precautionary safety measures are taken for this period. These include the following:
  - never attempting a nightshift unless it is supervised by an experienced, reliable person;
  - making sure that at least one person working the nightshift has a current first aid certification;
  - checking which helicopter pilots are licensed for night flights, and making sure they are readily available should an accident occur;
  - making provisions in camp for a radio contact person;
  - since walking down trees is the most dangerous aspect of a nightshift, consider walking down line, before dark, that has been targeted for completion during the nightshift, to eliminate the need for such activity during the night; and
  - if an accident should occur during the night, a helipad

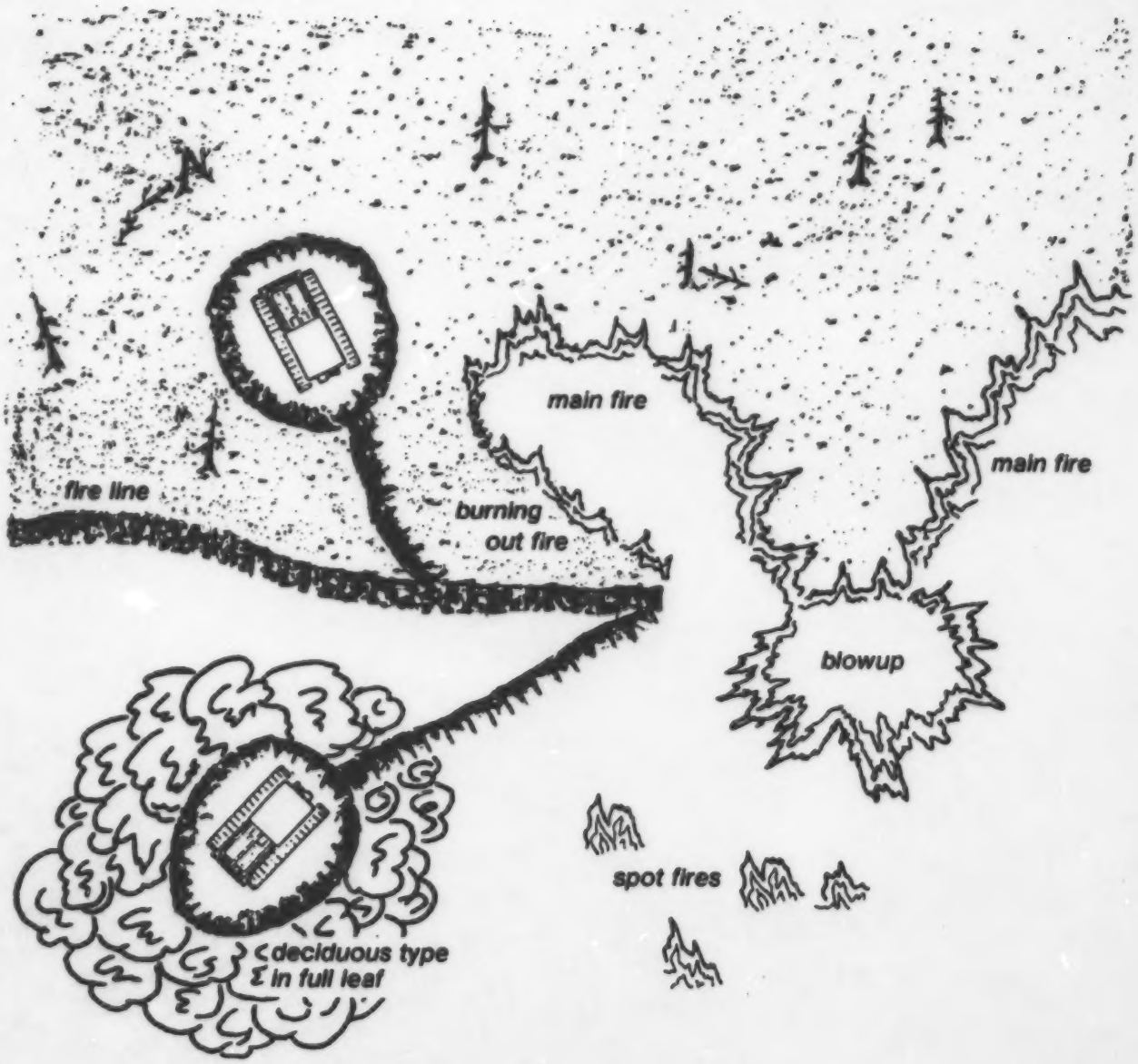


Figure 8. Protection of a bulldozer in a burned area or in a deciduous stand.

should be constructed near the victim, or move the victim to the nearest helipad if back/neck injuries have not been sustained. If back/neck injuries are suspected, a paramedic team should be sent to the accident site. Two bulldozers should be stationed at opposite sides of the helipad with their lights shining towards the helipad. The cat boss can use a flashlight to direct the pilot to land.

- Making sure that all helicopter personnel and other people traveling in helicopters are briefed on safety procedures. Emphasis should be placed on the main and tail rotors and how to avoid being struck. Safety features include the following:
  - approaching and leaving the helicopter in clear view of the pilot;
  - approaching and leaving the helicopter on the downslope side only;
  - approaching and leaving the helicopter in a crouched position;
  - never carrying anything near the helicopter that is above shoulder level;
  - using proper chin straps to secure hard hats so that such headgear is not blown off by the rotor wash;
  - removing unnecessary items from around the helipad, especially light articles such as tarps, pop cans and cardboard. Other slightly heavier articles must be sufficiently weighted down;
  - never throwing/tossing items or tools during loading or unloading;
  - using the proper procedures for closing doors and compartments;
  - wearing seatbelts at all times; and
  - placing seatbelts on the seat when leaving the helicopter, rather than allowing them to hang out the door and possibly damage the paint and skin of the helicopter during flight.
- Making sure that all personnel are within a safe area that can

be easily seen from the air during aerial ignition operations, especially if gel is to be used.

9.3 Bulldozer Operator Responsibilities

Bulldozer operators must be made aware of their direct responsibilities regarding safety. Operators are responsible for the following areas:

- personnel and machine safety;
- the actions of his own machine regarding other personnel and equipment. Before beginning work, the operator must make sure that no one is underneath or near his bulldozer;
- daily maintenance and upkeep of his bulldozer;
- ensuring that winching and towing operations are conducted safely; and
- the safety of any passengers.

9.4 Airtanker Drops

All fire personnel must be aware that serious injury or death can result if a person is hit by an airtanker load or the debris and falling trees associated with a drop. This requires that communications be established before any drop occurs, with backup measures in place in case of error or misunderstanding.

The birddog officer will probably conduct some "dummy runs" during his reconnaissance when he arrives at the fire. These are trial runs to ensure safe, effective, airtanker drops. This method is used often to demonstrate the target to tanker pilots by pulling up sharply at the proposed drop site.

The birddog officer will advise ground crews of where and when the drop will take place, and where personnel should take refuge. Since further drops may occur immediately, workers are to remain in a safe

area until notified to resume work. In addition to verbal communication, the birddog officer will fly the proposed flight path with the siren in a continuous yelp mode. Caution is advised for ground crews, since several drops may be made without any further dummy runs.

Just before the airtanker makes its drop, it is said to be on its final run. Although airtanker groups operate on their own radio frequency, silence should be observed on all frequencies for safety purposes. This also allows the birddog officer to concentrate on the drop, analyzing accuracy and safety factors. When the drop has been completed, the birddog plane will make another pass with the siren on an intermittent wailing mode.

Before the drop occurs, ground crews and equipment should be moved well away from the drop site in case of an inaccurate drop and to avoid retardant drift. Bulldozer operators should be instructed on the proper procedures to follow if they are concerned that they will be hit with a load while working. These procedures include the following:

- To avoid being hit from the side, the bulldozer should be turned to face the direction of the oncoming load; this allows the canopy to take the main impact as well as some of the flying debris.
- The operator should crouch down on the floor of the bulldozer to avoid being directly struck by debris.

If ground personnel are in danger of being hit by a drop, they should quickly determine where the load is likely to hit, and move a safe distance away at right angles to the drop. If this is not possible, the following procedures should be followed:

- Do not panic or run.
- Lie face down into the direction of the drop so the hard hat will take the brunt of the impact.

- Hold onto a stable object to avoid being thrown backwards.
- Stay clear of snags and dead branches.
- Keep away from hand-tools.
- Do not return to the fireline until all drops have been made.
- After the drop, be aware that most retardants are extremely slippery and will affect movement.

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